Transf.

RAILWAY MECHANICAL ENGINEER

Founded in 1832 as the American Rail-Road Journal

With which are also incorporated the National Car Builder, American Engineer and Railroad Journal, Railway Master Mechanic, and Boiler Maker and Plate Fabricator. Name Registered, U. S. Patent Office.

January, 1938

Volume 112 *No. 1*

Cars:

Reading Installs a Light Streamline Train..... 1

Locomotives:

The Locomotive Front End 5
Force-Feed Oil Lubrication 12
Failures of Locomotive Parts 15

Editorials:

It Is To Smile! 19
Tolerance 19
New Shop Equipment Will Pay For Itself..... 19
Welding Saves 20
Structural Defects In Freight Cars 21

Gleanings from the Editor's Mail:..... 22

The Reader's Page:

Failures in Crosshead and Piston-Rod Key Slots..... 23
Thermal Checks in Engine-Truck Wheels Eliminated..... 23

Car Foremen and Inspectors:

Car-Building Practice at the D. & H. Shops..... 24
The Lubrication of Railroad Equipment..... 27
Sand Blast Gun with Flat-Mouthed Orifice..... 29
Decisions of Arbitration Cases 29
Questions and Answers on the AB Brake..... 30
Combination Brush and Water Spray 30

Back Shop and Enginehouse:

Three Shop Devices at Danville 31
Hydraulic Press Brake and Flanging Machine..... 33
There Are More Ways Than One (A Walt Wyre Story). 34
Locomotive Boiler Questions and Answers..... 37
Tests of Elesco Tangential Steam Dryer..... 37

News..... 38

Index to Advertisers.....(Adv. Sec.) 52

Published on the second day of each month by

Simmons-Boardman Publishing Corporation

1309 Noble street, Philadelphia, Pa. Editorial and Executive Offices: 30 Church street, New York, and 105 West Adams street, Chicago. Branch offices: Terminal Tower, Cleveland; 1081 National Press bldg., Washington, D. C.; 1038 Henry bldg., Seattle, Wash.; Room 1001, 485 California street, San Francisco, Calif.; Union Bank bldg., Los Angeles, Calif.

Samuel O. Dunn, *Chairman of Board, Chicago;* Henry Lee, *President, New York;* Lucius B. Sherman, *Vice-Pres., Chicago;* Cecil R. Mills, *Vice-Pres., New York;* Roy V. Wright, *Vice-Pres. and Sec., New York;* Frederick H. Thompson, *Vice-Pres., Cleveland;* Elmer T. Howson, *Vice-Pres., Chicago;* Frederick C. Koch, *Vice-Pres., New York;* Robert E. Thayer, *Vice-Pres., New York;* H. A. Morrison, *Vice-Pres., Chicago;* John T. DeMott, *Treas. and Asst. Sec., New York.*

Roy V. Wright
Editor, New York

C. B. Peck
Managing Editor, New York

E. L. Woodward
Western Editor, Chicago

H. C. Wilcox
Associate Editor, New York

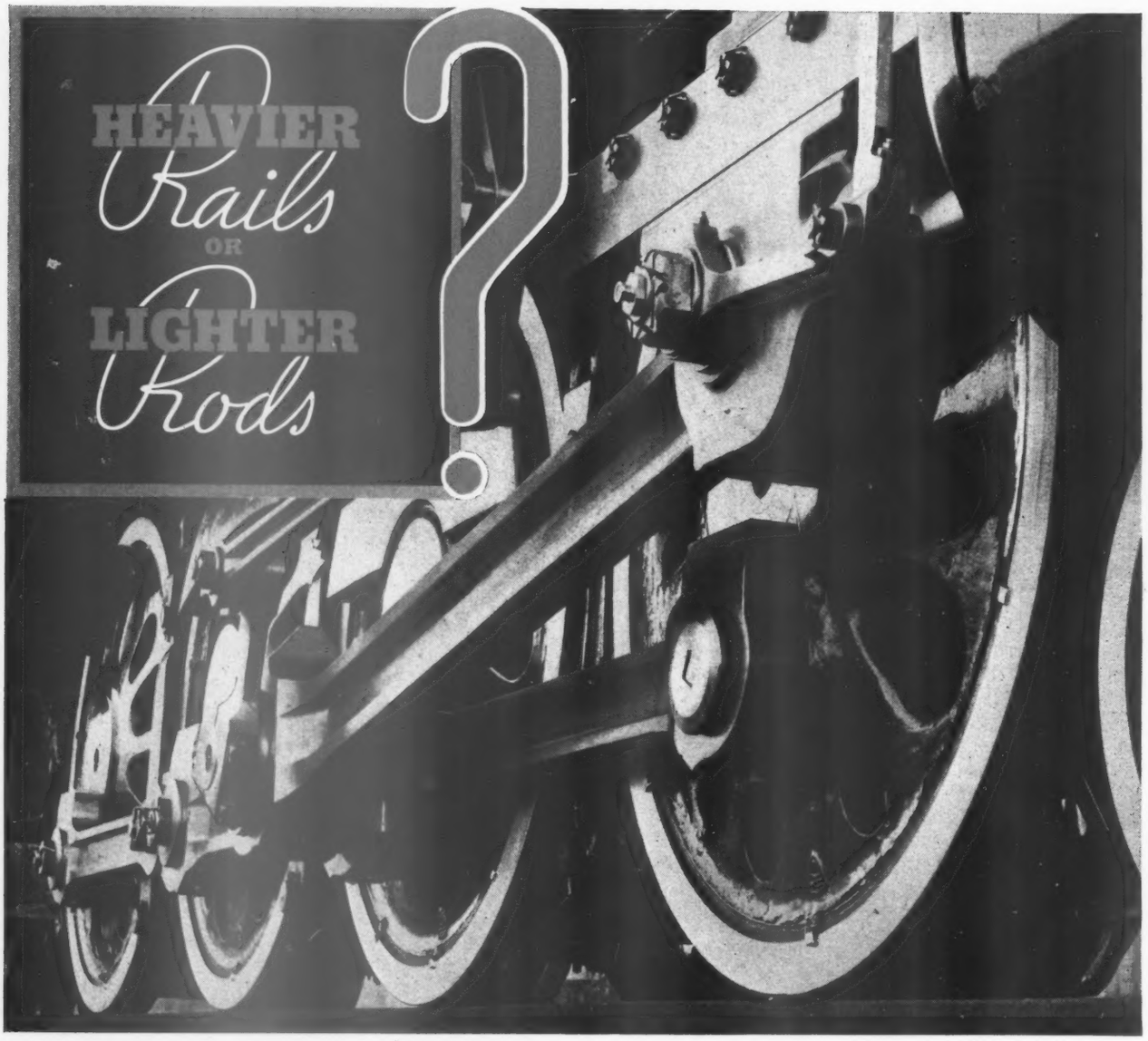
W. J. Hargest
Associate Editor, New York

Robert E. Thayer
Vice-Pres. and Business Manager, New York

Subscriptions (including, when published, the daily editions of the Railway Age, published in connection with the convention of the Association of American Railroads, Mechanical Division), payable in advance and postage free, United States, U. S. possessions and Canada: 1 year, $3; 2 years, $5. Foreign countries, not including daily editions of the Railway Age: 1 year, $4; 2 years, $7. Single copies, 35 cents. Address H. E. McCandless, circulation manager, 30 Church street, New York.

The Railway Mechanical Engineer is a member of the Associated Business ...s (A. B. P.) and the Audit Bureau of Circulations (A. B. C.), and ...dexed by the Industrial Arts Index and also by the Engineering Index Service.

TRANSPORTATION LIBRARY



Train speed is a major rail question—not how fast the locomotive can run, but what speed the rail can stand. » » » Regardless of locomotive type, maximum train speed is determined by the driver weights with the counter-balances down. » » » Agathon* Alloy Steel for reciprocating and revolving parts reduces the blow on the rail to a minimum. Its greater strength and greater resistance to vibration and shock permits parts of lighter section. » » » With parts of Agathon Alloy Steel permissible speeds can be higher and safety and economy of operation improved. » » » For that new power; for replacements on existing power our engineers will gladly work with you—no obligation. Address Department RA.

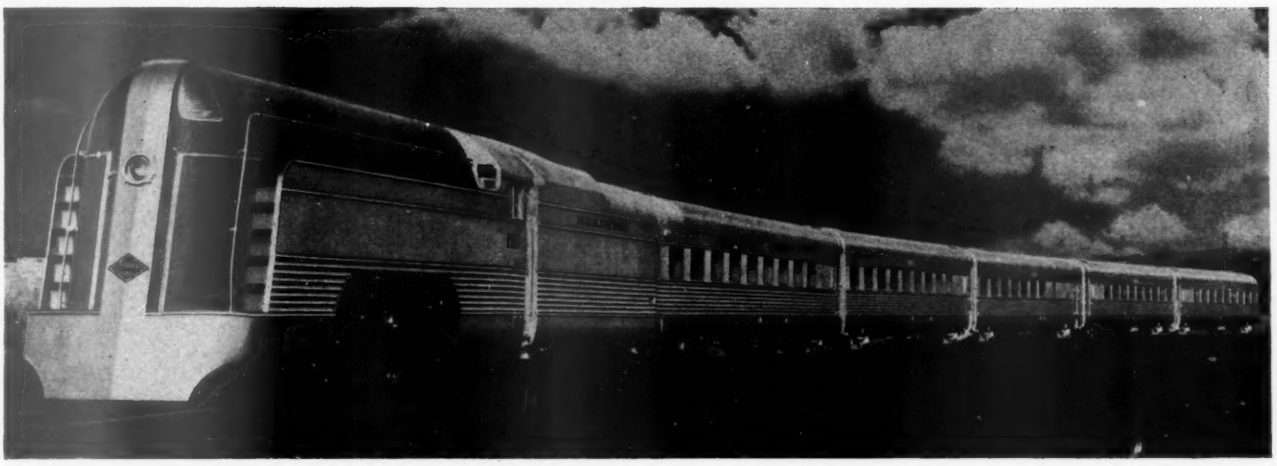
*Reg. U. S. Pat. Off.

Republic Steel Corporation

REPUBLIC STEEL

GENERAL OFFICES...CLEVELAND, OHIO ALLOY STEEL DIVISION . MASSILLON, O.

RAILWAY
MECHANICAL ENGINEER



Reading Installs

A Light Streamline Train

Five cars of Budd stainless-steel construction running on fast schedule between Philadelphia and New York — The train is symmetrical about the diner in the center — Hauled by a streamline Pacific type locomotive

On December 13 the Reading Company placed in service on the Reading-Jersey-Central line between New York and Philadelphia, Pa., a lightweight streamline stainless-steel train of five cars built by the Edward G. Budd Manufacturing Co. The train is drawn by a Pacific type steam locomotive remodelled and streamlined at the Reading shops of the railroad. The lines of the locomotive conform with the sheathing of the cars, thereby presenting a continuity of line and surface throughout the train.

The train is made up of four chair cars and one tavern-dining car. The two end chair cars are constructed as observation cars to obviate the necessity of turning the entire train around after its arrival at either terminal. The end cars each contain 56 coach seats and 14 individual lounge chairs and the other chair cars each have 56 coach seats and 12 individual lounge chairs. The dining car accommodates 24 passengers at tables in the dining room and 27 passengers in the tavern or cocktail lounge.

The Car Structures

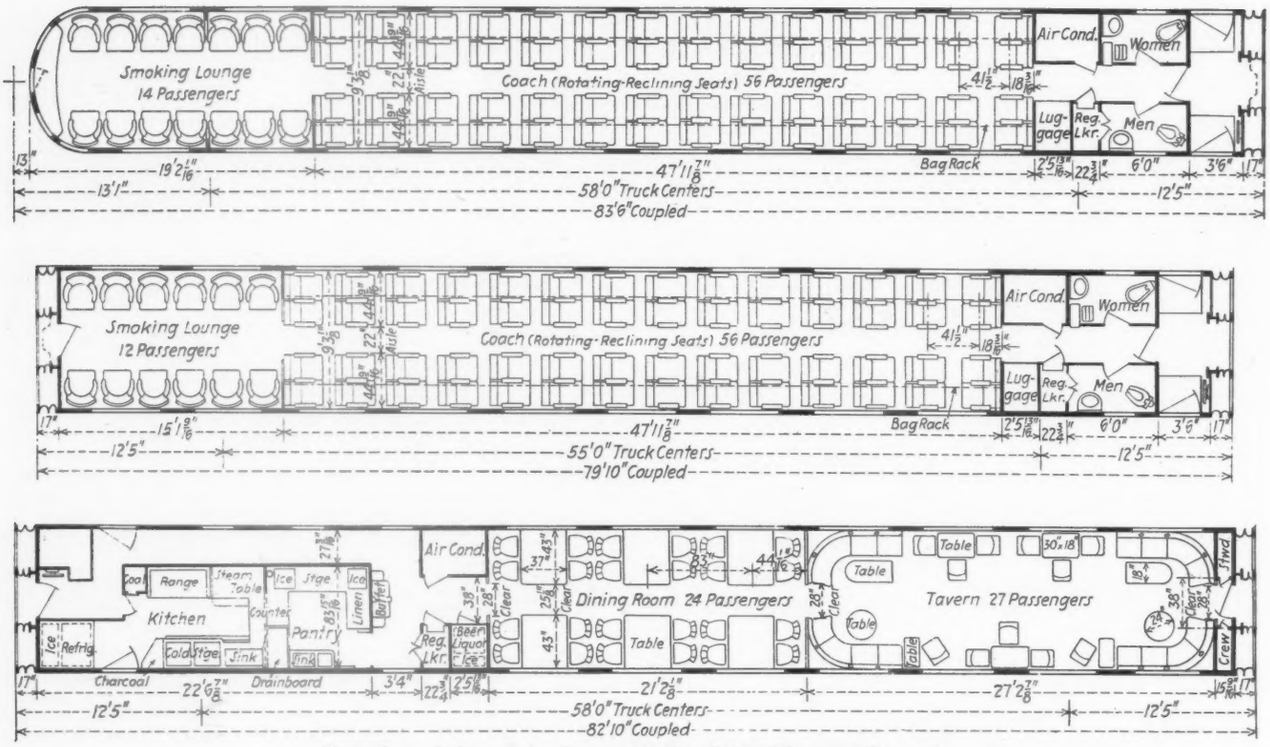
All car sheathing and structure, except the end underframes, are the well-known 18-8 stainless steel. This is used in two strengths. The high-tensile material has a tensile strength of 150,000 lb. per sq. in. and is used where light weight and strength are of prime importance, and the low-tensile material has a tensile strength of 100,000 lb. per sq. in. and is used where workability or special finishes is required. The Budd Shotweld process was used in the fabrication of these cars.

Fundamentally, the structure of the cars is a modified girder wherein the roof and under structure serve as compression and tension chords, and the two modified Pratt-truss side frames are the webs. The end structure is designed to withstand buffing, traction, vertical and lateral loads that are to be expected in service and as required by Railway Mail Service. The end underframes are made of Cromansil steel, arc welded into a unit, subsequently stress relieved and riveted to reinforced body members.

Doors are of all-metal construction, with a light of ¼-in. shatterproof glass in the upper portion. The stainless steel used in the outside doors is in harmony with the exterior metal. The passenger steps are so constructed that they are raised into the car body when the vestibule trap doors are closed, presenting a smooth exterior appearance.

All passenger side windows are double-glazed, with ¼ in. polished plate glass in the outer frame and ¼-in. shatterproof plate glass in the inner frame, with about ¼ in. air space between them. The outer window frames are attached directly to the car body, while the inner sash is hinged at the top to facilitate cleaning. The window frames are of all-metal construction and the glass is held in place by molded rubber strips. The toilet-room windows are single-glazed, with shatterproof flashed opal glass.

The cars are thoroughly insulated. The side walls, floors, roofs and ends are insulated with Stonefelt and the windows are of double-glazed construction to further reduce heat losses. The side, end and roof insulation



Floor plans of the cars in the new Reading lightweight streamline train

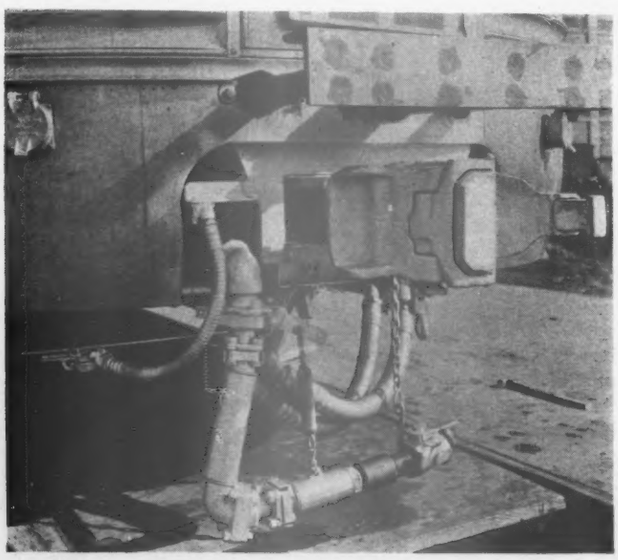
is held in place by metal clips and bands. The sub-floor insulation is supported by flat sheets of stainless steel on the under side.

Air Conditioning and Lighting

The Airtemp electro-mechanical air-conditioning equipment comprises a compressor-condenser unit of about 6½ tons' capacity mounted beneath each car floor, and an evaporator unit placed in a locker in each car body. A controllable amount of filtered fresh air is taken through louvered openings in the car roof, mixed with air drawn from the passenger compartment and forced through the conditioning unit and into the distributing duct which is made of galvanized steel insulated with ½-in. Deadnox. This duct, which is placed above the ceiling between the light ducts, allows the air to escape through a concealed narrow slot in the lower edge of each side. Incorporated in the evaporator is a steam heater coil of about 80,000 B.t.u. capacity for use when heated air is required. Finned copper-tube steam radiators are placed at the base of the walls for general car-heating purposes. The Vapor heating system is employed, with Barco steam-heat connections between the cars.

This train is the first complete installation of the Vapor correlative control of both heating and cooling. With this control system the only manual operation required is in changing over from cooling to heating or vice versa. In cooling the differential between the inside and outside temperatures is effected automatically under the control of an adjuster thermostat located in the fresh-air intake. With an outside temperature of

Details of the underframe and side construction



One of the controlled slack couplers

A side frame in process of fabrication

100 deg. or higher the inside temperature of the car is under control of an 80-deg. maximum thermostat. For each 3-deg. drop in outside temperature below 100 deg. F. a drop of 1 deg. is automatically effected in the temperature inside the car until the inside temperature has dropped to 72 deg. Should the outside temperature drop below 72 deg. with the control set for cooling, the adjuster thermostat is automatically dropped out of the circuit, thus preventing any further lowering of the inside temperature under outside temperature control. Both the overhead and floor heat are tied in the same automatic circuit controlled by an adjuster thermostat, in this case located in the recirculating air duct. This is set for a 3-deg. differential between the overhead and floor heat.

A separate ventilation system is installed in the kitchen. Fresh filtered air is delivered directly to the kitchen without passing over evaporator coils and is moved by exhaust ventilators, the capacity of which slightly exceeds that of the intake blowers. One intake blower feeds two ducts which extend along the sides of the doorway between the kitchen and dining room. These ducts deliver a curtain of air across the doorway, which is drawn into the kitchen by the action of the exhaust fans, thereby preventing the escape of kitchen odors.

The electrical system operates at 32 volts d.c. The current is supplied by Exide 1,000-amp. hr. batteries and the Safety Car Heating & Lighting Co. 20-kw. generators. The batteries are carried in a stainless-steel battery box mounted beneath the car. The generator is mounted longitudinally under the car and connected to an axle by the D.R. drive—a combination of vee belts, bevel gears and longitudinal drive shaft.

Provision is made for the operation of the air-conditioning equipment from a standby source of power. The motors are built for operation on both 32-volt d.c. and 220-volt a.c. The cars are equipped with both d.c. and three-phase a.c. receptacles for receiving standby power.

Direct and indirect concealed lighting is used in various parts of the cars. The indirect lights are concealed in two ducts recessed in the ceiling. The ducts are painted white and reflect light onto the car ceiling to create an almost shadowless illumination in the car. Direct lighting supplements the indirect system in the lounges, dining room and tavern. The cove over the windows is constructed behind the side ceiling lining

Weights of Cars in Reading Lightweight Streamline Train

Car No.	Weight, lb.
1	98,914
2	95,774
3	110,399
4	96,024
5	98,914
Total	500,025

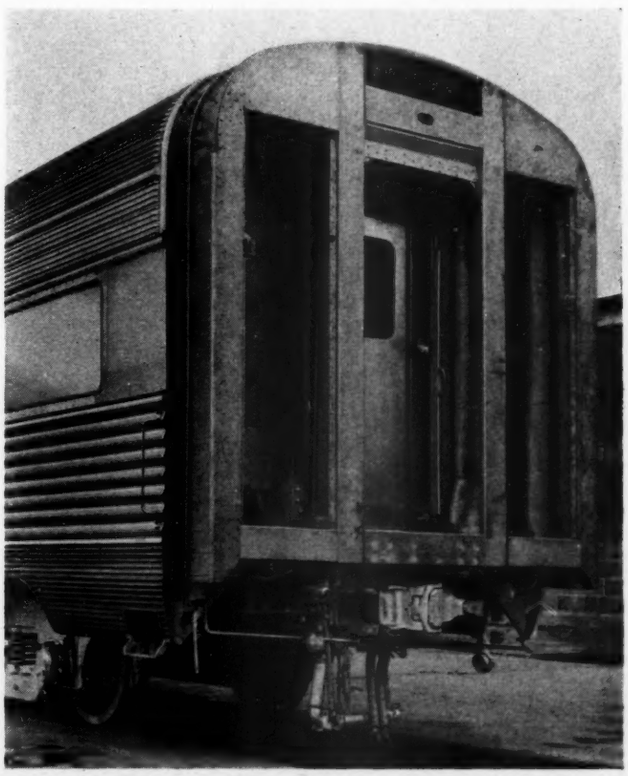
and is glazed on the under side in a horizontal plane, the light from this source offering comfortable reading conditions to passengers in the sections so equipped. Bag-rack fixtures in the coaches are centered over each seat and concentrate their light downward.

The vestibules, aisles and toilets are lighted from overhead fixtures recessed into the ceilings of these sections.

The power brake is the Westinghouse Air Brake Company's electro-pneumatic modified H.S.C., operated by air pressure supplied by the locomotive and controlled electrically. There is a belt-driven speed governor on each of two trucks on the train which controls braking pressures at various speeds. The hand brakes are of the wheel type mounted on a lightweight housing.

The Trucks

The cars are carried on four-wheel trucks of the conventional equalized swing bolster type. The wheel base measures 9 ft. Each truck is fitted with four Houde



End of coach showing the full-width diaphragm

Looking from the lounge section in one of the coaches

hydraulic shock absorbers to dampen the lateral swing action. Vibration and sound deadening is controlled by the use of insulation at strategic points. All castings are alloy steel, heat treated, and the equalizers are forged steel, machined all over. The axles are fitted with 36-in. multi-wear wheels and Fafnir combined ball- and roller-bearing journal boxes. The radial load is carried on hardened solid rolls, while the lateral thrusts are resisted by high-capacity ball bearings. The bearing housing is of alloy steel, hardened, and is reversible for double wear. The trucks are fitted with the Simplex Unit Cylinder clasp brakes.

Interior Treatment

The end cars are identical in layout and structure, but differ in color treatment. In one of the cars the main features of the color scheme are olive brown walls and coral upholstery; in the other they are aquamarine and chamois. Similarly, the second and fourth cars are alike in arrangement, but one is decorated with clay color on the side walls and green upholstery, and the other with olive-green walls and brown frieze upholstery. In addition to the roller shades, drapes are placed at the sides of the windows in all of the cars.

The floor plans indicate that each of four cars has a smoking lounge. Those at the ends of the train each seat 14 passengers in individual chairs and each is fitted with a table in the rounded end of the lounge, with shelves at the sides. The lounge in each of the other two coaches seats 12 passengers in individual chairs. The passenger compartments in each of these four cars is fitted with the rotating type, two-passenger seats, with individual reclining backs and sliding cushions. The cushions are molded sponge rubber and the backs are of spring construction. The individual arm chairs in the lounges are of wood-frame construction with molded sponge-rubber cushions and spring backs. The flooring in all four coaches is Linotile in a checkerboard pattern, the colors varying from car to car. Each car has a man's and a woman's toilet adjoining the vestibule.

The middle car in the train is a 24-passenger dining room, with a tavern compartment seating 27 persons at wall seats and individual chairs at small tables, and a kitchen and pantry. The kitchen equipment comprises a refrigerator at the extreme end of the kitchen; a coal range and water boiler; a broiler; two coal bins, one with a crew's locker above it; a steam table; a coffee urn, which stands on the steam table but with the faucet projecting into the pantry; two sinks with swivel faucets, one in the kitchen and one in the pantry; a service shelf; a low kitchen refrigerator; a fruit chill box; a liquor refrigerator and liquor locker, and numerous small lockers and compartments for the storage of dishes and supplies. All equipment in the kitchen is made of stainless steel, with the exception of the coal-burning range, and all exposed side wall is covered with sheet stainless steel. The miscellaneous hardware is chromium plated.

The dining room and tavern are decorated in olive-brown with touches of red and the upholstering is tan leather with red piping. The floor covering in both rooms is Seamloc carpet in raisin and henna. A Velvetex pad is placed under the carpet.

The Locomotives

The locomotives, two of which have been streamlined for use with this train, are the road's Class GISA Pacific type, some of which were originally built by the railroad

The vestibule open, showing the step operating mechanism

at its Reading shops. The two locomotives in question are from this group. They develop a tractive force of 40,900 lb., with a boiler pressure of 220 lb., cylinders 25 in. in diameter by 28 in. stroke, and driving wheels 80 in. in diameter. The boiler has a total evaporative heating surface of 2,984 sq. ft. The superheating surface is 621 sq. ft. and, originally built for anthracite service, the firebox has a grate area of 94.5 sq. ft.

The locomotive and tender have been shrouded and

(*Continued on page 18*)

A Study, Based on Laboratory Results, of

The Locomotive Front End

Part I

By H. S. Vincent*

An investigation of the laws which govern the flow of steam and gas in a locomotive front end — The author discusses the feasibility of reducing back pressure in locomotive cylinders

THE comprehensive tests of a front-end model,[1] recently made by E. G. Young and his associates, has served to focus attention upon a part of the steam locomotive which has been the subject of more or less empirical treatment since the days of Stephenson. The forces operating in the locomotive front end and the method of controlling them are better understood through the model experiments of Young as well as through the work of earlier investigators. Applying the laws of similarity, there is every reason to assume that the principles involved in the experiments with the model apply with equal force to the actual locomotive.

For the past thirty years, practically every coal-burning locomotive has been equipped with a modification of the Master Mechanics front-end arrangement, adopted in 1906 by the American Railway Master Mechanics Association and described in its proceedings for that year. In a recent report to the Mechanical Division of the Association of American Railroads,[2] presented by its Committee on Locomotive Construction, the continued use of the Master Mechanics type of locomotive front end is recommended and rules are promulgated for the area of the various gas passages, based on maintaining a definite proportion of the area through tubes and flues.

In this discussion, it is the author's purpose to attempt an investigation of the laws which govern the flow of steam and gas in a locomotive front end and to determine the feasibility of reducing back pressure in the locomotive cylinders. In making this study, data from the most recent laboratory tests of locomotives have been used and in addition some of the earlier data have been employed. In Table I, the principal character-

* Consulting Engineer, East Harwich, Mass.

[1] "A Study of The Locomotive Front End, Including Tests of A Front-End Model," by E. G. Young, Bulletin 256 of the Engineering Experiment Station, University of Illinois, Urbana, Ill., May 30, 1933. Also, "A Supplementary Study of the Locomotive Front End by Means of Tests on A Front-End Model," by E. G. Young, Bulletin 274 of the Engineering Experiment Station, University of Illinois, Urbana, Ill., May 21, 1935.

[2] Abstracted in the August, 1936, issue of the *Railway Mechanical Engineer*, page 339.

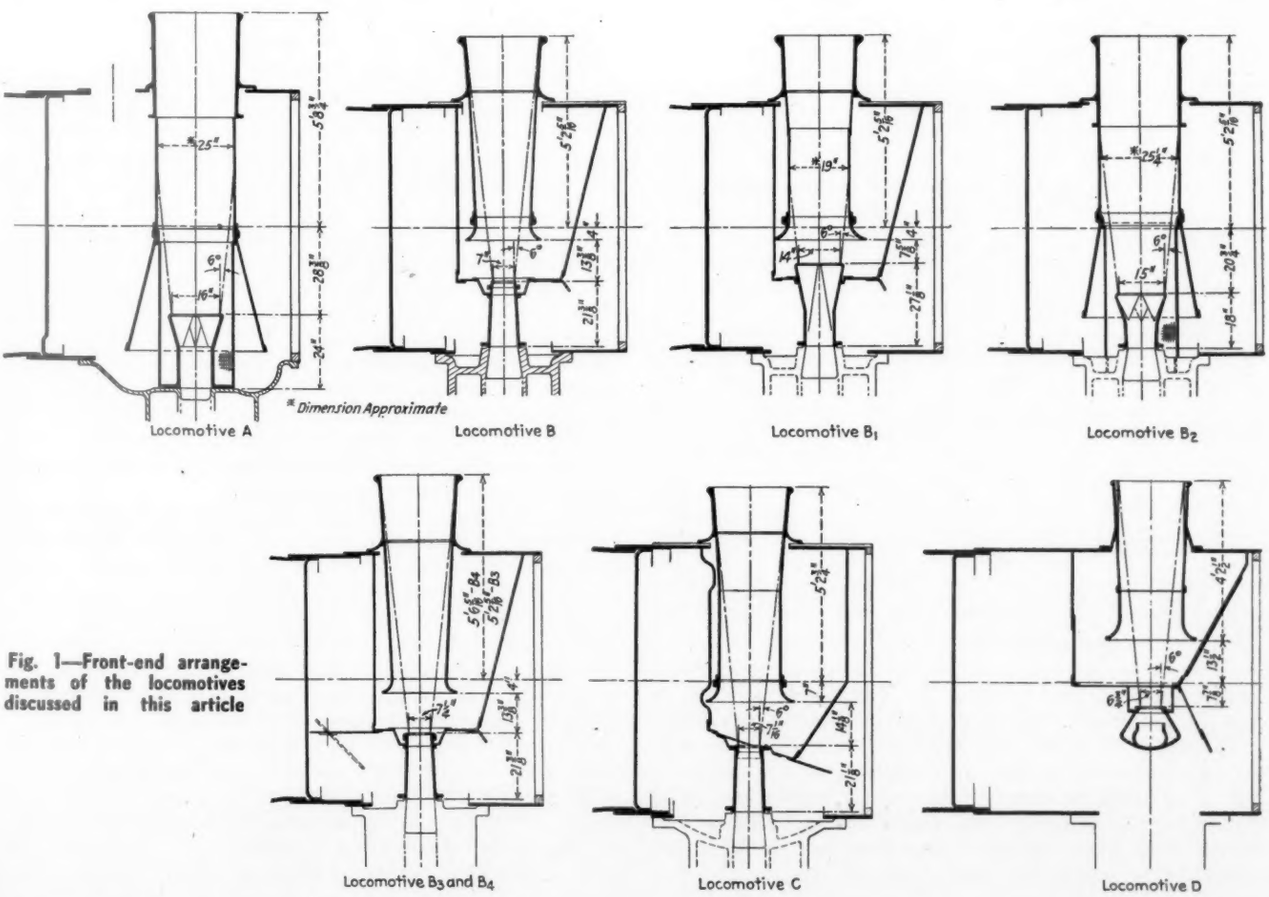


Fig. 1—Front-end arrangements of the locomotives discussed in this article

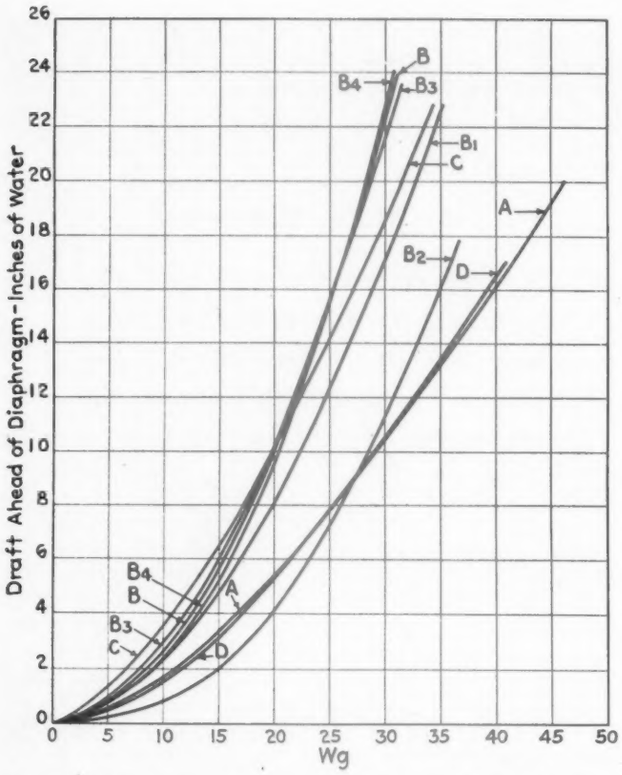


Fig. 2—Relation between Wg and the draft ahead of the diaphragm

istics of the locomotives here discussed are given. Much of the data here used have not been published. The writer wishes to express his gratitude to those who furnished them.

The pertinent data relating to the operation of the drafting apparatus for the eight locomotives under discussion are assembled in Table II. These data are taken from the test records and are assembled in the order of the weight of fuel fired per hour per square foot of grate surface, column 2. Tests were selected to give the maximum operating range of fuel consumption.

Table I—Principal Proportions and Characteristics of the Eight Locomotives

Locomotive designation	*A*	*B*	B_1	B_2	B_3	B_4	*C*	*D*
Wheel arrangement	4-8-2	4-6-2	4-6-2	4-6-2	4-6-2	2-8-2	2-10-0	2-10-2
Cylinder diameter, in.	27	27	27	27	27	27	30½	27
Piston stroke, in.	30	28	28	28	28	30	32	32
Number of cylinders	2	2	2	2	2	2	2	3
Wheel diameter, in.	72	80	80	80	80	62	62	63½
Working pressure, lb. per sq. in.	250	205	205	205	205	205	250	350
Number of tubes	120	237	237	237	237	237	114	206
Number of flues	170	40	40	40	40	40	200	50
Diameter of tubes, in.	2¼	2¼	2¼	2¼	2¼	2¼	2¼	2¼
Diameter of flues, in.	3½	5½	5½	5½	5½	5½	3¼	5½
Length of tubes and flues, ft.—in.	19—1	19—0	19—0	19—0	19—0	19—0	19—0	23—0
Evaporative heating surface, sq. ft.	4,696	4,041	4,041	4,041	4,041	4,041	4,799	5,192
Combustion chamber length, in.	98	36	36	36	36	36	42	61
Firebox volume, cu. ft.	582	427	427	427	427	427	364	683
Type of superheater	E	A	A	A	A	A	E	A
Grate area, sq. ft.	70	70	70	70	70	70	70	82½
Type of grate	Table	Table	Table	Table	Finger	Finger	Finger	Finger
Stoker or hand fired	Stoker	Hand	Hand	Hand	Hand	Hand	Stoker	Stoker
Feedwater heater	With	None	None	None	None	None	With	With

Note: For front-end arrangement see Fig. 1.

The types of front end, applied to the eight locomotives at the time the tests were conducted, are shown in Fig. 1. It will be observed in the examples here cited that two types of nozzle were used, the Goodfellow and the six-point star. Adequate data were not available for a locomotive using any other type of nozzle. In five of the eight tests here shown, viz., locomotives *B*, B_1, B_2, B_3 and B_4, the boilers and smokeboxes are identical in design. This presents an excellent opportunity for assessing the effect of a change in the structure of the front-end arrangement.

In the operation of the locomotive front end, the gases of combustion generated in the firebox are moved forward over the boiler heating surfaces by the entraining action of the steam jet, which also induces a differential pressure between the firebox and smokebox. The weight of gases moved in a given time is a function of the pressure and weight of steam emerging from the nozzle.

Pressure difference between the interior of the smokebox ahead of the diaphragm and that of the atmosphere, as measured in inches of water, is usually designated as

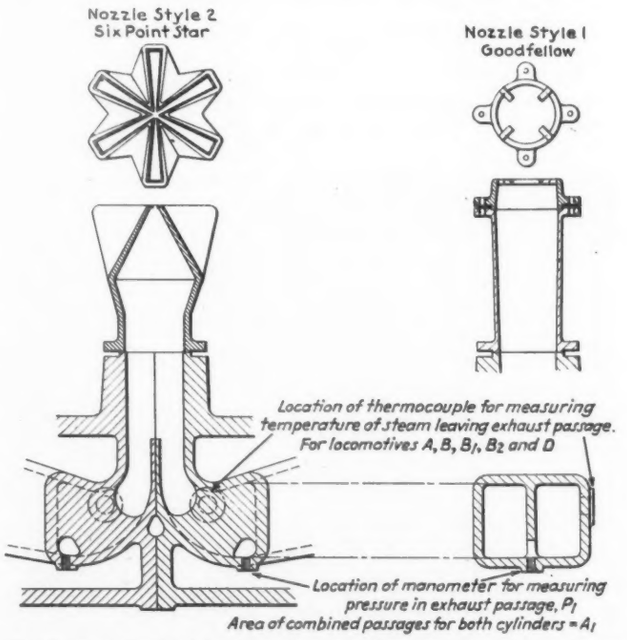

Nozzle Style 2
Six Point Star
Nozzle Style 1
Goodfellow
Location of thermocouple for measuring temperature of steam leaving exhaust passage. For locomotives A, B, B1, B2 and D
Location of manometer for measuring pressure in exhaust passage, P1
Area of combined passages for both cylinders = A1

Fig. 3—Location of instruments for measuring pressure and temperature of exhaust steam and types of nozzle used in the tests

the draft. With a given boiler and smokebox arrangement, the weight of gas moved in unit time has a definite relation to the draft, but is not directly proportional, as shown in Fig. 2, for the eight locomotives under discussion. Recent investigators[1] have shown conclusively that the draft, depending as it does on the variable resistance offered to the passage of the gases, is not an accurate measure of the efficiency of a smokebox arrangement. It has been shown that the weight of gas moved per pound of steam issuing from the exhaust nozzle is a more accurate criterion.

Taking into consideration the whole operation of the locomotive or its overall efficiency, the writer would propose another standard for measuring the relative effectiveness of a front-end arrangement, viz., the weight of gas moved over the heating surfaces in unit time per pound pressure of steam exhausted from the cylinders. It is obvious that high back pressure is detrimental to locomotive operation, primarily because it reduces the work done in the cylinders. It will be shown that it is possible to reduce back pressure without decreasing the efficiency of the drafting apparatus.

In view of the importance of the subject, it may be well to review the principles involved in the action of the exhaust steam in drafting a locomotive. The operation of a locomotive exhaust nozzle is subject to the same

Table II—Original Draft Data From Tests of the Eight Locomotives

	Loco.	Test No.	Dry fuel, lb. per sq. ft. of grate surface per hr.	Water evaporated, lb. per hr.	Steam exhausted, lb. per hr.	Exhaust-steam conditions: Temp. t_1, deg. F.	Press. P_1, lb. per sq. in., abs.	Press. P_2 lb. per sq. in., abs.	$\Delta P = P_1 - P_2$	Enthalpy at P_1 and t_1, B.t.u. per lb.	Enthalpy at P_2, B.t.u. per lb.	Specific volume at P_1, cu. ft. per lb.	Specific volume at P_2, cu. ft. per lb.	Draft, in. of water: Ahead of diaphragm	Back of diaphragm	At rear tube sheet	At center of firebox	Speed, r.p.m.	Nominal cutoff, per cent	Mixed gas lb. per sq. ft. grate surface per hr.
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
	A	532	67.3	30,620	28,907	320	18.1	14.7	3.4	1200.98	1183.50	25.42	29.84	4.59	...	2.08	1.12	40	70	899.5
		539	80.5	35,170	32,890	347	19.1	14.7	4.4	1213.48	1190.94	24.94	30.47	5.74	...	2.70	1.65	40	80	1057.0
		511	94.4	41,024	39,029	326	20.3	14.7	5.6	1203.36	1176.47	22.83	29.25	6.83	...	3.79	1.64	80	60	1202.0
		520	105.4	44,632	43,080	278	20.2	14.7	5.5	1180.49	1155.63	21.47	27.40	6.90	...	3.75	1.83	320	30	1217.0
		521	108.8	44,655	43,007	278	20.3	14.7	5.6	1180.47	1155.44	21.36	27.36	7.06	...	3.99	2.03	200	40	1215.0
		530	112.8	47,644	45,592	360	21.9	14.7	7.2	1219.21	1185.30	22.09	30.00	8.66	...	4.76	2.43	80	70	1380.0
		519	122.0	48,677	46,815	306	21.5	14.7	6.8	1193.57	1163.39	20.97	28.10	8.45	...	4.70	2.27	160	50	1418.0
		526	128.1	50,210	48,091	288	21.8	14.7	7.1	1184.90	1154.40	20.16	27.32	8.41	...	4.43	2.37	240	40	1313.0
		531	146.9	54,369	51.565	399	24.3	14.7	9.6	1237.25	1192.75	20.88	30.72	10.00	...	4.88	2.95	80	80	1558.0
		527	174.6	63,583	61,193	405	28.1	15.5	12.6	1239.56	1188.26	18.14	28.75	13.42	...	6.22	3.36	120	70	1855.0
		523	231.2	74,339	71,863	420	33.2	18.3	14.9	1246.08	1193.57	15.62	24.75	16.20	...	7.22	4.15	200	60	2208.0
		536	260.9	83,944	80,678	453	38.2	21.1	17.1	1261.33	1207.53	14.10	22.33	18.30	...	7.43	4.54	200	70	2016.0
		537	327.4	89,262	86,584	474	41.4	22.8	18.6	1271.08	1214.96	13.29	21.07	19.95	...	8.04	4.83	200	76	2250.0
	B	415A	48.0	27,184	27,135	225	17.8	14.7	3.1	1155.40	1143.37	22.54	26.26	4.88	3.09	2.15	1.29	240	30	725.5
		416A	82.1	41,918	41,853	272	22.9	14.7	8.2	1176.90	1143.61	18.73	26.35	10.88	6.59	4.60	2.64	240	44	1883.5
		418A	107.6	52,826	52,719	319	28.3	15.6	12.7	1198.76	1151.46	16.15	25.60	15.13	9.13	6.15	3.33	240	53	1252.0
		420A	162.8	61,592	61,592	350	33.2	18.3	14.9	1212.54	1163.44	14.32	22.69	17.60	10.95	7.48	3.95	240	61	1360.0
	B_1	427A	32.4	30,115	30,115	223	18.1	14.7	3.4	1154.10	1139.50	22.07	25.91	5.18	3.47	2.03	1.13	240	29	836.0
		424A	83.5	42,001	42,001	265	22.0	14.7	7.3	1173.75	1143.58	19.31	26.35	10.70	7.25	4.63	2.34	240	44	1155.0
		425A	118.4	53,956	53,820	310	27.3	15.0	12.3	1194.34	1147.14	16.55	26.21	15.79	10.35	6.52	3.27	240	53	1440.0
		430A	127.1	53,796	53,712	307	26.8	14.7	12.1	1197.87	1151.36	16.79	26.68	15.95	10.38	6.22	3.51	240	53	1447.5
		431A	151.6	63,058	62,865	344	31.3	17.2	14.1	1209.96	1161.04	15.08	23.90	19.59	12.30	7.01	4.40	240	60	1687.5
		429A	186.3	70,350	70,286	370	36.8	20.3	16.5	1221.62	1174.01	13.23	20.96	21.85	13.26	7.04	4.56	240	67	1780.0
	B_2	438A	49.4	29,328	29,328	226	17.2	14.7	2.5	1156.15	1144.52	23.38	26.38	2.86	...	1.88	1.09	240	26	780.5
		434A	78.4	40,498	40,420	248	19.3	14.7	4.6	1166.24	1145.79	21.50	26.50	4.80	...	2.93	1.67	320	35	1205.0
		435A	86.8	44,640	44,601	261	20.5	14.7	5.8	1172.23	1147.03	20.63	26.66	6.47	...	4.35	2.75	240	44	1160.0
		436A	109.2	55,576	55,660	301	24.7	14.7	10.0	1190.54	1150.04	18.09	26.95	9.33	...	5.95	3.52	240	52	1406.0
		437A	140.6	64,925	64,754	328	28.9	15.9	13.0	1202.66	1155.34	16.00	25.36	11.55	...	6.96	4.14	240	59	1593.0
		441A	148.1	64,831	64,664	340	28.5	15.7	12.8	1208.50	1159.80	16.49	26.12	10.94	...	5.87	3.71	240	61	1650.0
		440A	184.2	72,759	72,620	365	32.7	18.0	14.7	1219.85	1170.40	14.82	23.50	12.75	...	6.76	4.06	240	66	1635.0
		439A	185.7	72,049	71,990	369	32.5	17.9	14.6	1221.77	1172.87	14.84	23.51	13.45	...	7.36	4.91	240	67	1594.0
	B_3	4051	28.4	19,502	19,184	217	16.2	14.7	1.5	1152.00	1144.94	24.58	26.45	2.0	1.5	...	0.50	320	16	482.0
		4020	35.6	22,499	20,372	218	16.5	14.7	1.8	1152.40	1141.70	24.08	26.31	2.6	1.8	...	0.50	160	24	482.5
		4050	48.5	28,893	28,699	225	18.9	14.7	4.2	1154.90	1136.85	21.19	25.70	4.8	3.1	...	1.00	320	23	652.0
		4059	67.2	37,803	37,803	246	21.6	14.7	6.9	1164.60	1136.60	19.13	25.73	8.1	5.3	...	1.30	240	38	914.5
		4013	89.5	44,598	43,715	255	23.3	14.7	8.6	1168.43	1134.73	17.95	25.58	10.3	6.7	...	2.10	200	45	937.0
		4069	124.4	57,586	53,597	322	26.1	14.7	11.4	1200.10	1154.29	17.59	27.37	15.1	10.1	...	2.80	320	51	1037.0
		4068	130.4	56,700	55,924	317	28.0	15.4	12.6	1197.56	1150.26	16.28	25.79	14.	9.0	...	2.70	120	69	1266.5
		4049	143.4	59,953	58,170	332	30.1	16.6	13.5	1204.50	1156.45	15.45	24.50	16.3	9.2	...	2.10	280	53	...
		4054	170.5	65,400	65,319	343	33.8	18.6	15.2	1208.96	1160.06	13.93	22.05	18.8	11.7	...	2.90	200	60	1495.0
	B_4	3923	56.1	30,594	30,594	227	19.6	14.7	4.9	1155.87	1135.01	20.51	25.60	4.8	3.6	...	1.30	120	43	659.5
		3932	76.3	38,628	38,413	249	22.2	14.7	7.5	1165.54	1135.38	18.67	25.63	7.9	5.8	...	1.60	100	55	863.2
		3921	86.8	44,708	44,584	266	24.2	14.7	9.5	1173.72	1134.67	17.56	25.79	9.8	6.6	...	1.70	160	52	1025.0
		3926	96.3	45,450	44,889	275	24.3	14.7	9.6	1177.77	1140.08	17.70	26.07	10.6	7.5	...	2.20	170	53	1045.0
		3945	112.4	47,508	47,508	306	25.1	14.7	10.4	1192.84	1151.44	17.92	27.08	10.8	7.6	...	2.60	120	61	1037.5
		3928	127.8	55,760	55,705	327	28.8	15.8	13.0	1202.39	1154.12	16.05	25.43	15.1	10.5	...	2.50	170	62	1214.0
		3927	148.7	58,640	58,256	326	30.6	16.8	13.8	1201.36	1153.37	15.06	23.86	16.1	10.8	...	2.90	160	62	1342.5
		3931	169.2	58,860	58,860	323	30.3	16.7	13.6	1199.79	1153.41	15.14	24.00	16.5	11.8	...	3.50	120	73	1345.0
	C	5935	56.7	28,050	27,290	244	18.7	14.7	4.0	1164.45	1146.40	22.07	26.55	6.2	4.2	...	1.20	40	49	692.5
		5919	68.4	32,930	31,844	235	19.7	14.7	5.0	1159.62	1138.37	20.65	25.86	5.8	4.4	...	1.20	80	39	778.0
		5940	79.9	33,300	32,298	249	19.7	14.7	5.0	1166.62	1144.96	21.09	26.40	7.7	5.3	...	1.10	40	56	712.0
		5971	97.1	41,400	40,195	242	21.7	14.7	7.0	1162.42	1144.96	18.91	25.51	8.8	6.2	...	1.50	120	40	897.0
		5939	103.0	41,600	40,517	252	22.7	14.7	8.0	1167.09	1135.74	18.35	25.65	9.2	7.1	...	1.30	60	57	899.0
		5933	127.1	49,500	48,310	299	25.7	14.7	11.0	1189.28	1146.28	17.33	26.65	12.9	9.6	...	1.60	80	57	1323.0
		6123	212.1	57,900	56,058	280	30.7	16.9	13.8	1178.69	1134.57	14.06	22.28	16.5	12.0	...	2.20	160	50	1310.0
		5973	228.5	58,400	57,184	298	28.7	15.8	12.9	1188.19	1142.79	15.46	24.50	13.9	10.7	...	2.20	180	52	1336.0
	D	7918	44.0	27,700	26,360	224	18.2	14.7	3.5	1154.76	1139.11	22.00	25.90	3.2	2.3	...	0.62	160	52-28	670.0
		7915	62.1	35,970	34,446	236	21.0	14.7	6.3	1159.67	1134.17	19.36	25.49	5.0	3.7	...	1.18	160	64-34	835.0
		7924	75.4	41,380	39,208	286	23.3	14.7	8.6	1183.59	1148.23	18.79	26.80	6.2	4.6	...	1.33	200	62-36	906.0
		7907	87.0	47,210	44,201	248	25.8	14.7	11.1	1164.62	1124.70	15.99	24.66	7.5	5.4	...	1.35	120	81-54	1044.0
		7925	112.2	55,560	52,925	317	28.9	15.9	13.0	1197.36	1150.26	15.72	24.97	8.6	6.3	...	1.59	200	71-47	1266.0
		7927	135.2	62,180	59,746	313	34.4	18.9	15.5	1194.31	1147.11	13.13	20.80	10.6	7.7	...	1.99	200	83-55	1296.0
		7923	143.4	61,610	59,148	308	34.5	19.0	13.5	1191.76	1145.66	13.00	20.60	10.7	8.0	...	2.31	200	82-52	1306.5

laws that govern the operation of any steam nozzle, regardless of the fact that its contour does not show the refinement of design that characterizes the turbine or ejector nozzle. There are in use on locomotives a variety of nozzle types from the plain circular form to the complicated grid and star types. The great majority of the steam locomotives in this country are equipped with the plain round nozzle. For the locomotives under discussion, the type of nozzle used is indicated more or less diagrammatically by Fig. 3. This figure serves also to show the location of the instruments used for measuring the pressure and temperature of the exhaust steam in the cylinder exhaust passages.

Table III—Nomenclature

A_1 = area of cylinder exhaust passage, sq. ft. at point where measurements P_1 and t_1 are taken.
A_2 = area of exhaust nozzle outlet, sq. ft.
P_0 = pressure in smokebox, ahead of diaphragm.
P_1 = steam pressure in exhaust passage, at A_1, lb. per sq. in., abs.
P_2 = steam pressure in exhaust nozzle, at A_2, lb. per sq. in., abs.
$\Delta P = (P_1 - P_2)$*.
t_1 = temperature of steam at A_1, deg. F.
V_1 = specific volume of exhaust steam at A_1, cu. ft. per lb.
V_2 = specific volume of exhaust steam at A_2, cu. ft. per lb.
H_1 = enthalpy of steam at A_1, B.t.u. per lb.
H_2 = enthalpy of steam at A_2, B.t.u. per lb.
$\Delta H = (H_1 - H_2)$.
M_t = theoretical weight of steam flowing through nozzle, lb. per sec.
M = actual weight of steam through nozzle, from tests, lb. per sec.
M_o = mean calculated weight of steam flowing through nozzle, lb. per sec.
W_t = theoretical velocity of flow through nozzle, ft. per sec.
W = actual velocity of flow through nozzle, ft. per sec.
$C = M_o / M_t = W / W_t$.
C_t = proportion of heat in steam appearing at nozzle.
Z = correction factor for initial velocity of steam at A_1.
W_g = weight of gas passing through boiler and smokebox, lb. per sec.
C_s = weight of gas per lb. of steam flowing through nozzle, lb.
C_g = weight of gas generated per lb. of coal burned, lb.
C_b = ratio of coal burned to coal fired.
$W_f = C_g C_b$ = lb. of gas per lb. of coal fired.
G = lb. of coal fired per hr. per sq. ft. of grate surface.
R_g = grate area, sq. ft.
K = calorific value of dry fuel, B.t.u. per lb.
F = evaporative efficiency of boiler.
m and n = constants used in determining boiler efficiency.
x and y = constants used in determining coefficient C.
E = total evaporation of boiler, lb. per hr.
E_1 = total steam flowing through nozzle, lb. per hr.
n and n_1 = constants used in relating M_o to P.
$\propto$ = varies as.
a = flare angle of steam jet.

* Values of ΔP from 0 to 12, inclusive, equal gage pressure.
Values of ΔP over 12 equal $(P_1 - 0.55 P_1)$.
When ΔP exceeds 12, $P_1 = \{ [15.3 (\Delta P - 12)] / 6.9 \} + 26.7$.

The standard equation for determining the velocity of steam flow per second through a nozzle, where the initial velocity is not a factor, is:

$$W_t = 223.7 \sqrt{\Delta H} \quad \ldots\ldots (1)$$

In the locomotive exhaust passage, the initial velocity of the steam at A_1, Fig. 3, is relatively high and must be accounted for. The equation then becomes:

$$W_t = 223.7 \sqrt{\frac{\Delta H}{1 - \left(\frac{A_2}{A_1}\right)^2 \left(\frac{V_1}{V_2}\right)^2}} \quad \ldots\ldots (2)$$

To facilitate calculation by slide rule, equation (2) can be more conveniently stated as:

$$W_t = 223.7 \sqrt{\Delta H} / \sqrt{Z} \quad \ldots\ldots (3)$$

where

$$Z = 1 - \left(\frac{A_2}{A_1}\right)^2 \left(\frac{V_1}{V_2}\right)^2 \quad \ldots\ldots (4)$$

The actual velocity of discharge through the nozzle is reduced by friction and other losses and is always less than W_t. Then

$$W = W_t C \quad \ldots\ldots (5)$$

The theoretical weight of steam per second passing through the nozzle is

$$M_t = \frac{223.7 \, A_2 \sqrt{\Delta H}}{V_2 \times \sqrt{Z}} \quad \ldots\ldots (6)$$

or

$$M_t = W_t A_2 / V_2 \quad \ldots\ldots (7)$$

The mean calculated weight of steam flowing through the nozzle per second is

$$M_o = M_t C \quad \ldots\ldots (8)$$

The product of equations (3), (4) and (5), as calculated from the test data for the eight locomotives under discussion, is shown in Table IV. These tables also give the values of A_1, A_2, and ΔH, as well as indicating the type of nozzle employed.

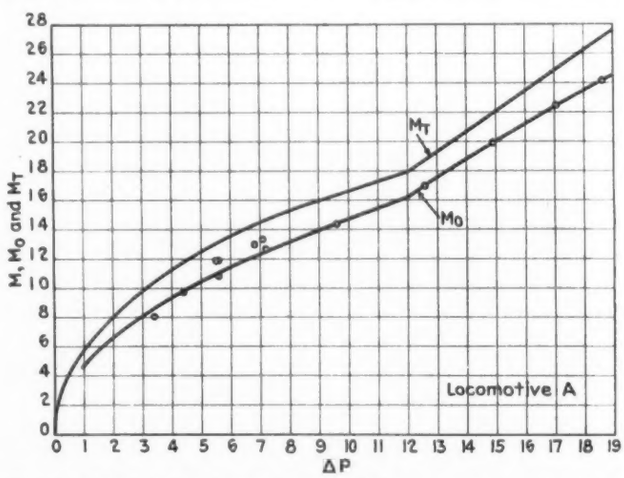


Fig. 4—Theoretical and actual steam flow per second as related to ΔP for locomotive A

The upper curve in Fig. 4 represents the value M_t as related to the pressure difference ΔP, for the locomotive A. Curves having the same characteristics were constructed for the eight locomotives. Locomotive A was selected for illustration because this test had a wider range than the others and is the most recent.

The lower curve in Fig. 4 represents the mean calculated value of the weight of steam per second M_o passing through the nozzle. It will be noted that this agrees with the actual test values M, as represented by the small circles. The nozzle coefficient is

$$C = M_o / M_t \quad \ldots\ldots (9)$$

It will be seen from Fig. 4 that when ΔP reaches a value of 12, there is an abrupt change in the contour of the curves M_t and M_o. This is caused by the difference in the value of P_2, which from 0 to 12 is 14.7 lb., and

In the tests of locomotives B_3, B_4 and C, the temperature t_1 of the exhaust steam was measured with mercury thermometers placed near the cylinders, consequently the readings are thought to be too high. For the remaining tests, the steam temperature was recorded by thermocouples located in the exhaust passages as shown in Fig. 3. For the earlier tests, the exhaust pressure P_1 was read from Bourdon gages fitted with a retard device to control the violent fluctuations in pressure. With this device it was found difficult to establish the true mean pressure. For the later tests, a mercury U-gage or manometer was used as recommended by the A. S. M. E. Power Test Code.

The symbols used in this discussion are shown in Table III.

Table IV—Calculated Data Based on Tests of the Eight Locomotives

1 Test No.	2 Type of nozzle	3 Area of steam passage in cylinder, A_1 in Fig. 3, sq. ft.	4 Area of nozzle outlet, A_2 in Fig. 3, sq. ft.	5 Heat drop ΔH between A_1 and and A_2, B.t.u. per lb.	6 M, lb.	7[a] W, ft. per sec.	8[b] W_t, ft. per sec.	9 $\frac{W}{W_t}$	10 $\left(\frac{A_2}{A_1}\right)^2$	11 $\left(\frac{V_1}{V_2}\right)^2$	12[c] Z
Locomotive *A*:											
532	S	0.959	0.321	17.48	8.03	746	976	0.764	0.1120	0.726	0.9186
539	S	0.959	0.321	22.54	9.13	866	1104	0.785	0.1120	0.671	0.9248
511	S	0.959	0.321	26.89	10.84	988	1178	0.839	0.1120	0.610	0.9316
520	S	0.959	0.321	24.86	11.96	1020	1156	0.882	0.1120	0.615	0.9311
521	S	0.959	0.321	25.03	11.95	1018	1160	0.878	0.1120	0.612	0.9314
530	S	0.959	0.321	33.91	12.65	1182	1344	0.880	0.1120	0.543	0.9392
519	S	0.959	0.321	30.18	13.00	1138	1269	0.897	0.1120	0.558	0.9375
526	S	0.959	0.321	30.50	13.35	1136	1275	0.891	0.1120	0.544	0.9390
531	S	0.959	0.321	44.50	14.32	1370	1532	0.984	0.1120	0.461	0.9484
527	S	0.959	0.321	51.30	16.98	1520	1638	0.928	0.1120	0.398	0.9553
523	S	0.959	0.321	52.51	19.96	1538	1658	0.928	0.1120	0.398	0.9553
536	S	0.959	0.321	53.80	22.41	1559	1679	0.928	0.1120	0.398	0.9553
537	S	0.959	0.321	56.12	24.04	1577	1713	0.921	0.1120	0.398	0.9553
Locomotive *B*:											
415A	G	1.286	0.250	12.03	7.54	792	787	1.006	0.0378	0.738	0.9721
416A	G	1.286	0.250	33.29	11.63	1225	1303	0.941	0.0378	0.505	0.9809
418A	G	1.286	0.250	47.30	14.64	1498	1550	0.967	0.0378	0.398	0.9849
420A	G	1.286	0.250	49.10	17.10	1551	1579	0.983	0.0378	0.398	0.9849
Locomotive B_1:											
427A	S	1.286	0.280	14.60	8.34	780	870	0.896	0.0474	0.726	0.9656
424A	S	1.286	0.280	30.17	11.67	1098	1245	0.882	0.0474	0.537	0.9745
425A	S	1.286	0.280	47.20	14.96	1400	1550	0.904	0.0474	0.398	0.9811
430A	S	1.286	0.2948	46.51	14.92	1350	1540	0.877	0.0526	0.398	0.9790
431A	S	1.286	0.2948	48.92	17.46	1415	1581	0.895	0.0526	0.398	0.9730
429A	S	1.286	0.280	49.32	19.52	1461	1585	0.922	0.0474	0.398	0.9811
Locomotive B_2:											
438A	S	1.286	0.3335	11.63	8.15	644	784	0.822	0.067	0.800	0.9462
434A	S	1.286	0.3335	20.45	11.24	893	1035	0.863	0.067	0.659	0.9557
435A	S	1.286	0.3335	25.20	12.40	992	1139	0.871	0.067	0.600	0.9729
436A	S	1.286	0.3335	40.50	15.46	1249	1445	0.865	0.067	0.403	0.9698
437A	S	1.286	0.3335	47.32	18.00	1368	1560	0.877	0.067	0.398	0.9732
441A	S	1.286	0.3335	48.70	17.97	1408	1583	0.890	0.067	0.398	0.9732
440A	S	1.286	0.3335	49.45	20.20	1422	1594	0.893	0.067	0.398	0.9732
439A	S	1.286	0.3335	48.90	19.99	1408	1585	0.889	0.067	0.398	0.9732
Locomotive B_3:											
4051	G	1.196	0.2655	7.06	5.32	530	607	0.872	0.0493	0.861	0.9576
4020	G	1.196	0.2655	8.42	5.66	561	748	0.750	0.0493	0.837	0.9588
4050	G	1.196	0.2655	18.05	7.97	772	967	0.798	0.0493	0.679	0.9660
4059	G	1.196	0.2655	28.00	10.50	1018	1200	0.849	0.0493	0.553	0.9727
4013	G	1.196	0.2655	33.70	12.15	1170	1315	0.890	0.0493	0.493	0.9757
4069	G	1.196	0.2655	45.81	14.88	1535	1530	1.004	0.0493	0.413	0.9796
4078	G	1.196	0.2655	47.30	15.63	1507	1554	0.976	0.0493	0.398	0.9804
4049	G	1.196	0.2655	48.05	16.15	1490	1566	0.952	0.0493	0.398	0.9804
4054	G	1.196	0.2655	48.90	18.14	1506	1580	0.954	0.0493	0.398	0.9804
Locomotive B_4:											
3923	G	1.196	0.2665	20.86	8.49	816	1033	0.790	0.0497	0.642	0.9681
3932	G	1.196	0.2665	30.16	10.68	1027	1245	0.825	0.0497	0.531	0.9736
3921	G	1.196	0.2665	37.05	12.38	1197	1377	0.797	0.0497	0.464	0.9763
3926	G	1.196	0.2665	37.69	12.47	1220	1390	0.878	0.0497	0.461	0.9771
3943	G	1.196	0.2665	41.40	13.20	1342	1455	0.810	0.0497	0.438	0.9782
3928	G	1.196	0.2665	48.27	15.47	1477	1570	0.941	0.0497	0.398	0.9802
3927	G	1.196	0.2665	47.99	16.20	1450	1565	0.927	0.0497	0.398	0.9802
3931	G	1.196	0.2665	46.38	16.35	1472	1538	0.957	0.0497	0.398	0.9802
Locomotive *C*:											
5935	G	1.188	0.2495	18.05	7.58	807	965	0.836	0.0441	0.692	0.9695
5919	G	1.188	0.2495	21.25	8.84	916	1045	0.876	0.0441	0.635	0.9713
5940	G	1.188	0.2495	21.66	8.96	948	1055	0.898	0.0441	0.635	0.9719
5971	G	1.188	0.2495	27.70	11.15	1140	1191	0.957	0.0441	0.549	0.9758
5939	G	1.188	0.2495	31.35	11.25	1157	1266	0.914	0.0441	0.512	0.9774
5933	G	1.188	0.2495	43.00	13.41	1432	1480	0.968	0.0441	0.422	0.9814
6123	G	1.188	0.2495	44.12	15.57	1390	1496	0.930	0.0441	0.398	0.9824
5973	G	1.188	0.2495	45.40	15.87	1558	1522	1.023	0.0441	0.398	0.9824
Locomotive *D*:											
7918	G	0.884	0.2308	15.65	7.32	822	908	0.905	0.0681	0.722	0.9508
7915	G	0.884	0.2308	25.50	9.56	1056	1152	0.916	0.0681	0.577	0.9607
7924	G	0.884	0.2308	35.36	10.89	1265	1353	0.935	0.0681	0.429	0.9665
7907	G	0.884	0.2308	39.92	12.28	1312	1435	0.915	0.0681	0.491	0.9714
7925	G	0.884	0.2308	47.10	14.70	1590	1557	1.022	0.0681	0.398	0.9728
7927	G	0.884	0.2308	47.20	16.59	1496	1558	0.960	0.0681	0.398	0.9728
7923	G	0.884	0.2308	46.10	16.43	1466	1540	0.952	0.0681	0.398	0.9728

Notes: S refers to six-point star nozzle and G refers to Goodfellow nozzle. [a] See equation (5). [b] See equation (3). [c] See equation (4).

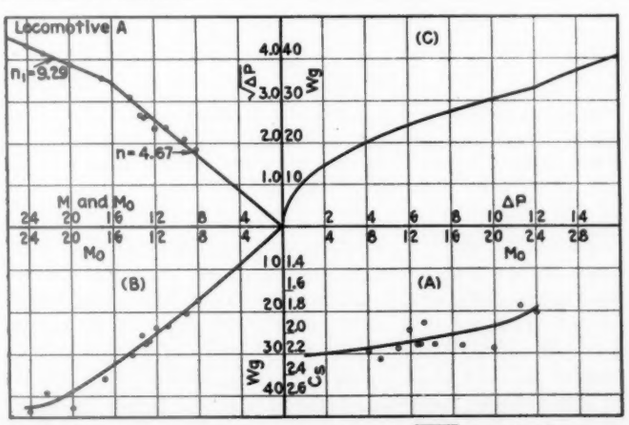


Fig. 5—Steam flow per second as related to $\sqrt{\Delta P}$, weight of gas per pound of steam, weight of gas flow per second, and gas flow as related to ΔP for locomotive *A*

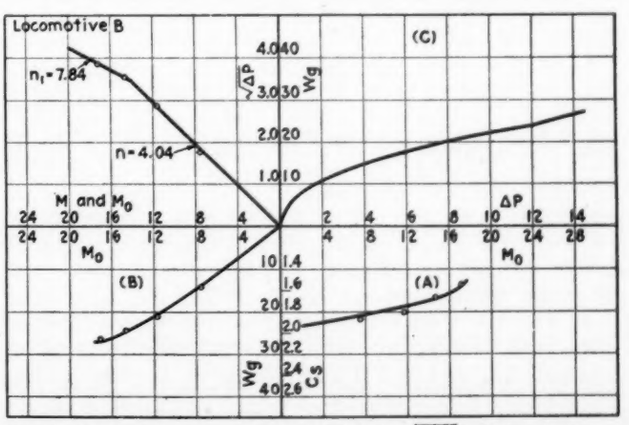


Fig. 6—Steam flow per second as related to $\sqrt{\Delta P}$, weight of gas per pound of steam, weight of gas flow per second, and gas flow as related to ΔP for locomotive *B*

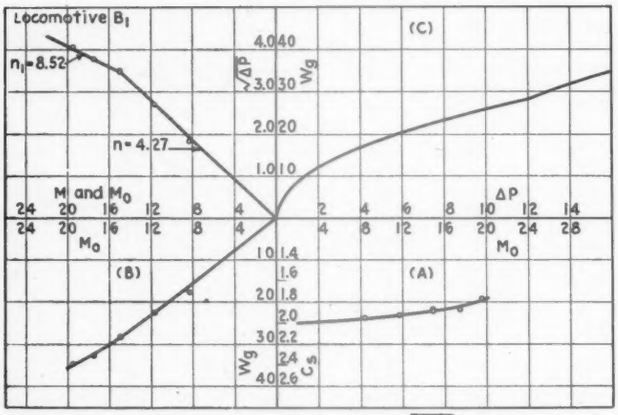


Fig. 7—Steam flow per second as related to $\sqrt{\Delta P}$, weight of gas per pound of steam, weight of gas flow per second, and gas flow as related to ΔP for locomotive B_1

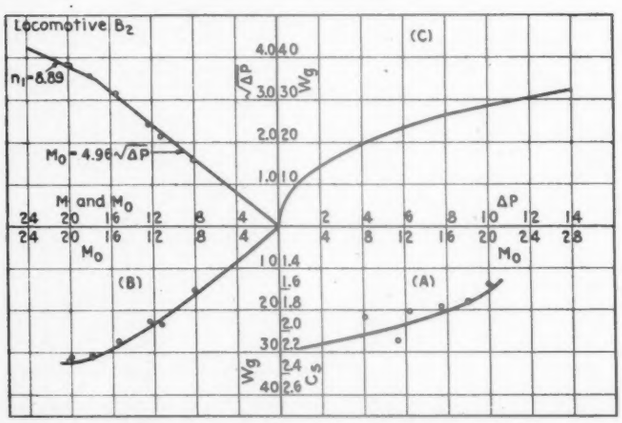


Fig. 8—Steam flow per second as related to $\sqrt{\Delta P}$, weight of gas per pound of steam, weight of gas flow per second, and gas flow as related to ΔP for locomotive B_2

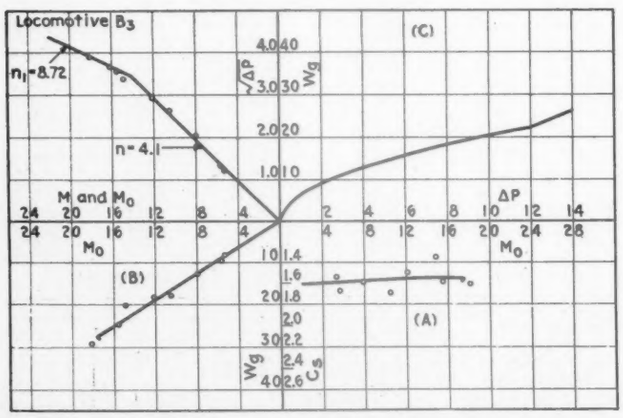


Fig. 9—Steam flow per second as related to $\sqrt{\Delta P}$, weight of gas per pound of steam, weight of gas flow per second, and gas flow as related to ΔP for locomotive B_3

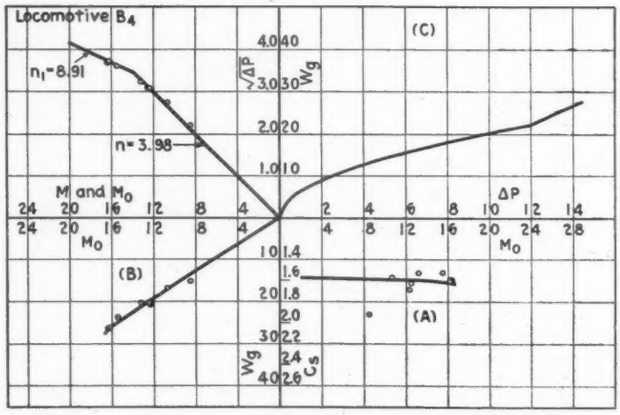


Fig. 10—Steam flow per second as related to $\sqrt{\Delta P}$, weight of gas per pound of steam, weight of gas flow per second, and gas flow as related to ΔP for locomotive B_4

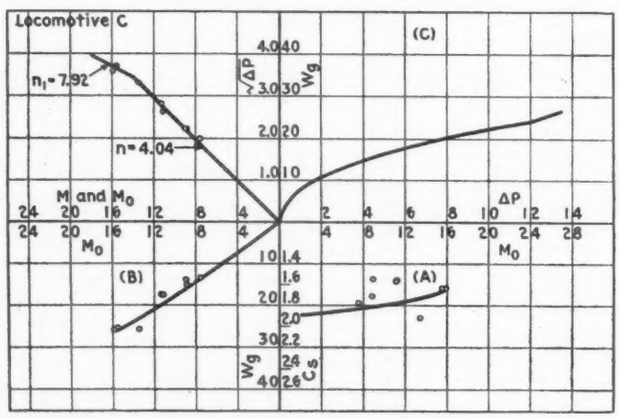


Fig. 11—Steam flow per second as related to $\sqrt{\Delta P}$, weight of gas per pound of steam, weight of gas flow per second, and gas flow as related to ΔP for locomotive C

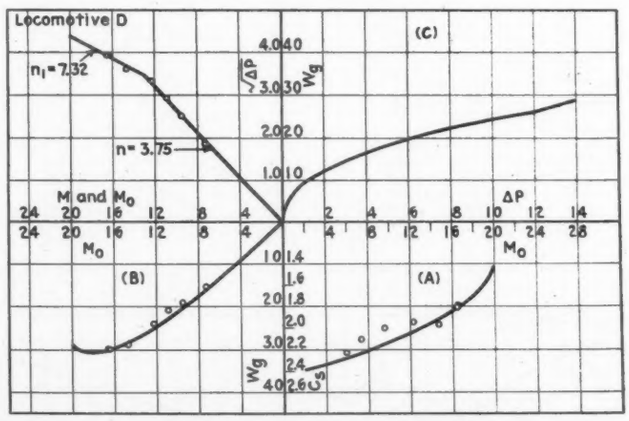


Fig. 12—Steam flow per second as related to $\sqrt{\Delta P}$, weight of gas per pound of steam, weight of gas flow per second, and gas flow as related to ΔP for locomotive D

above 12 is 0.55 P_1. This critical ratio for the flow of a fluid through an orifice is well known and enters into all nozzle calculations.

It was found by experiment that for all the locomotives being considered, there is a straight-line relation between M_o and $\sqrt{\Delta P}$. From zero to the critical pressure

$$M_o = n\sqrt{\Delta P} \quad \ldots\ldots\ldots\ldots\ldots\ldots (10)$$

while beyond the critical pressure

$$M_o = n_1(\sqrt{\Delta P} - \sqrt{12}) + n\sqrt{12} \quad \ldots\ldots\ldots\ldots\ldots (11)$$

For the majority of the tests cited, the value of ΔP does not extend much beyond 12. In these cases it is somewhat difficult to establish with certainty the value of the constant n_1, although it evidently approximates 2 n. For locomotive A, the range of the test was so extensive that the value of n_1 is easily established at 1.99 n.

The relation between M_o and ΔP is shown in Figs. 5 to 12, inclusive, for all of the eight locomotives. The actual steam flow M is also indicated in these figures by small circles. It is evident from these exhibits that be-

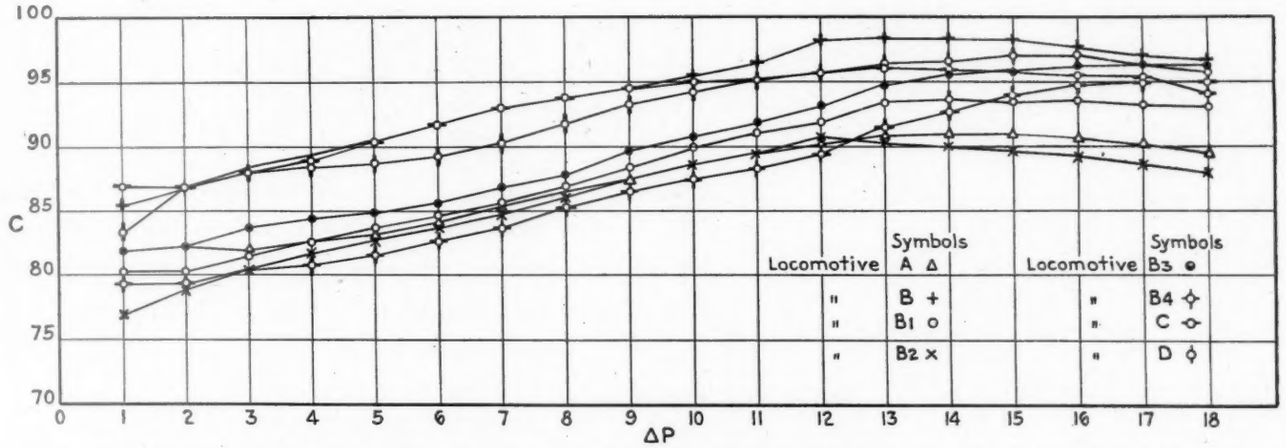


Fig. 13—Value of coefficient C in per cent, as related to $\triangle P$, for tests of the eight locomotives—Actual C = values given ÷ 100

yond the critical pressure the value of $\triangle P$ increases with the steam flow at a much lower rate than obtains below the critical pressure.

The coefficient C varies rather widely for the designs of locomotives tested; this is indicated by Fig. 13. As a rule, the value of C tends to increase with the flow up to the critical pressure. Beyond that point it either is constant or diminishes. The maximum variation for any given value of $\triangle P$ is approximately 10 per cent. The coefficient appears to vary inversely as the nozzle area, especially beyond the critical pressure. The writer has found it impossible to establish from the data available the law governing the variation in the value of C. There is nothing very definite in technical literature bearing on the probable value of C, in such a case. It can be closely estimated, for the tests cited, by the equation:

$$C = x - (yA_2) \quad \ldots\ldots\ldots\ldots\ldots\ldots (12)$$

in which the constants x and y, as related to $\triangle P$, are given in Fig. 14.

Table V—Calculated Data for Plotting Fig. 4

1	2	3	4[a]	5[b]	6[c]	7	8	9	10[d]	11[e]	12[f]	13[g]
P_1	P_2	ΔP	t_1	V_1	V_2	ΔH	$\sqrt{\Delta H}$	$(V_1V_2)^2$	Z	M_1	M_2	C
15.0	14.70	0.30	296	29.73	30.20	1.683	1.298	0.969	0.8915	3.27	....	....
16.0	14.70	1.30	303	28.13	30.05	6.690	2.587	0.876	0.9081	6.52	5.29	81.14
18.0	14.70	3.30	317	25.45	29.74	16.750	4.092	0.733	0.9178	10.31	10.31	82.06
20.0	14.70	5.30	330	23.29	29.52	25.550	5.054	0.622	0.9301	12.76	10.69	83.78
23.0	14.70	8.30	350	20.26	29.30	37.620	6.137	0.501	0.9439	15.48	13.47	87.02
26.0	14.70	11.30	370	18.81	29.19	48.200	6.941	0.415	0.9539	17.50	15.85	90.51
26.7	14.70	12.00	374	18.41	29.14	50.690	7.119	0.398	0.9554	17.95	16.39	91.33
27.0	14.85	12.15	375	18.22	28.85	50.730	7.120	0.398	0.9554	18.12	16.53	91.23
29.0	15.95	13.05	382	17.09	27.07	50.900	7.138	0.398	0.9554	19.36	17.60	90.94
32.0	17.60	14.40	390	15.63	24.78	51.400	7.170	0.398	0.9554	21.27	19.26	90.53
34.0	18.70	15.30	397	14.82	23.48	52.200	7.222	0.398	0.9554	22.60	20.40	90.20
42.0	23.10	18.90	421	12.32	19.53	53.320	7.301	0.398	0.9554	27.50	24.50	89.05

Notes: [a] Mean test results. [b] Values taken from steam tables. [c] See equation (13). [d] See equation (4). [e] See equation (6). [f] See equation (9). [g] See equation (12). For definition of terms in column heads and their units, see Table III.

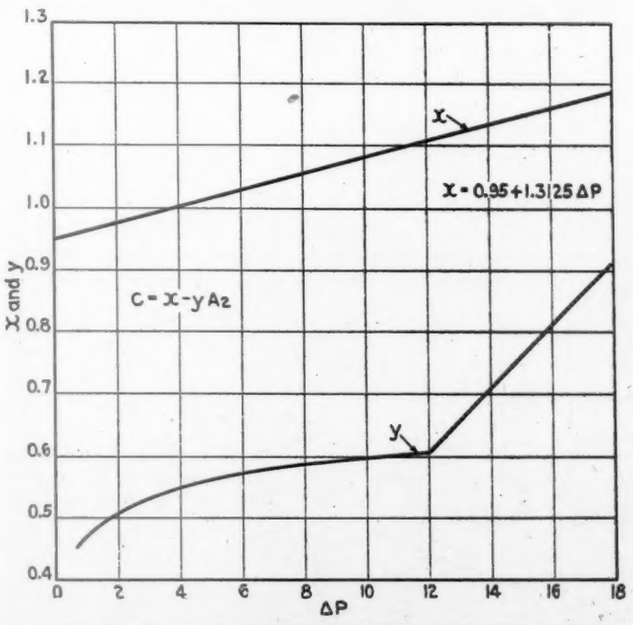


Fig. 14—Constants for determining value of coefficient C

The loss of energy in the exhaust passages and nozzle is due in part to friction between the steam and the enclosing walls, but is more largely due to the divergence of the expansion of the steam from the adiabatic or theoretical expansion of steam in a nozzle.

The standard steam tables are based on the assumption that when the temperature of superheated steam falls to the saturation point, it immediately begins to condense. Experiments [3] have proven that this is not true of expansion in a nozzle. Here the steam may be cooled well below the saturation temperature before condensation begins. The steam in this region will follow the law of expansion for superheated steam. This fact must be taken into consideration in establishing the values of V_2 and H_2. To determine these values under the condition of undercooling the following equations have been proposed:[4]

$$V_2 = V_1\left(\frac{P_1}{P_2}\right)^{0.77} \quad \ldots\ldots\ldots\ldots\ldots\ldots (13)$$

$$H_2 = H_1 - 0.802\,[(P_1V_1) - (P_2V_2)] \quad \ldots\ldots\ldots\ldots\ldots\ldots (14)$$

Equations (13) and (14) have been used throughout

[3] "Supersaturated Steam," by John I. Yellott, Jr., Trans. A. S. M. E., June, 1934, vol. 56, paper FSP-56-7, page 411.
[4] Ibid, Appendix No. 2.

(*Continued on page 18*)

Service Mileage Increased by

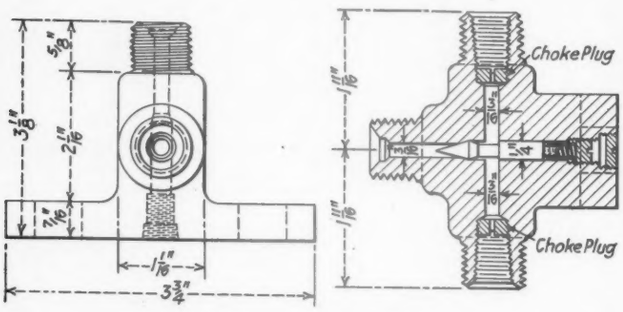
Force-Feed Oil Lubrication

Lehigh Valley is operating over 300 locomotives on which oil under pressure is distributed to the major wearing parts by the use of dividers

IN September of last year the Lehigh Valley unwheeled a Class L-5 eight-wheel switching locomotive, No. 3137, at the Perth Amboy, N. J. engine terminal for tire turning. This switcher was turned out of the Sayre, Pa. system shops in August, 1933, after receiving Class 3 repairs and had been in service for four years and one month, accumulating a total mileage of 64,712.

This locomotive is one of a number of the eight-wheel and Mikado type used in switching service on the Lehigh Valley that are equipped with force-feed oil lubrication for the principal working parts. The oil is supplied to the feed lines by either Nathan or Detroit mechanical lubricators and is distributed to the various points by means of two-, three- or four-way oil dividers of the type shown in one of the illustrations. These oil dividers were developed on the Lehigh Valley and are covered by patents.

The divider shown in the illustration is one of the two-way type. The oil enters from the lubricator under pressure and forces the needle valve open to admit it to the passage leading to the outlets. The spring controlling the action of the needle valve is set, for most locations, at 50 lb. per sq. in. The amount of oil passing



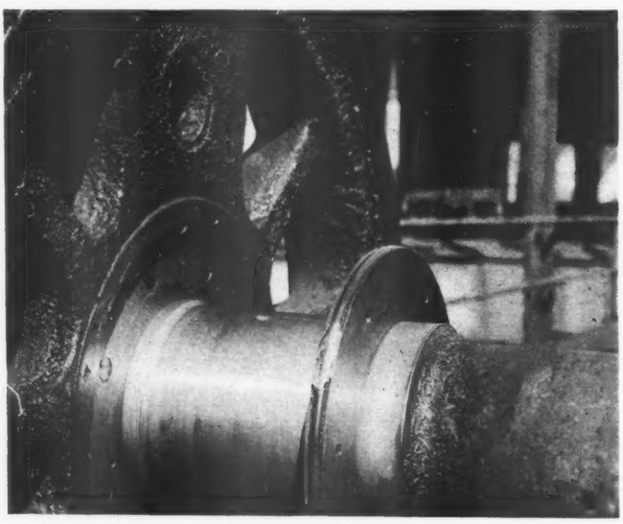
Details of a two-way divider

from the outlets of the dividers is controlled by the diameter of the hole in the choke plugs shown at the ends of the outlet passage. In the case of the type illustrated, the hole in the choke plug is 1/16 in. diameter.

On the eight-wheel switcher, the locations oiled are indicated in the diagrammatic sketch. Oil is supplied from an eight-feed mechanical lubricator and by means of dividers 21 points on the locomotive are oiled. One feed supplies two locations on the guides; four feeds supply eight locations on the four drivers—four crown brasses and four hub liners; one feed of the lubricator supplies the air compressor; the remaining two feeds supply four locations in the valves and cylinders. Dividers of the type described are not used on the air pump, valves or cylinders where lubrication is against high steam pressure.

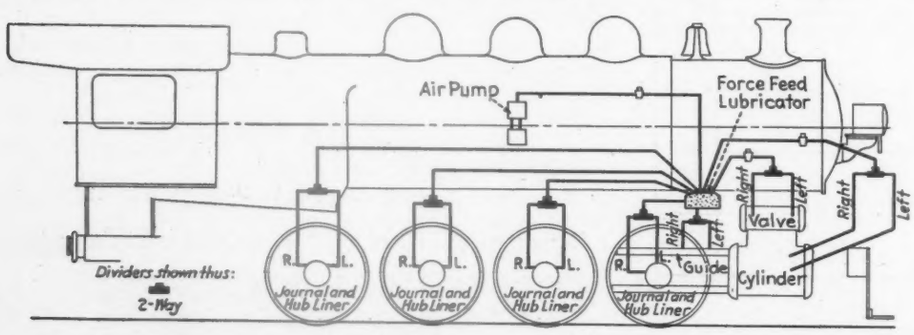
This same system of oil lubrication is also used on Pacific, 4-8-4 and other type locomotives of the Lehigh Valley.

Several years ago the Lehigh Valley adopted the use



The journals and hub liners on Engine No. 3137 were in excellent condition

of floating hub liners, which were equipped for oil lubrication, the oil being distributed by use of these oil dividers. This was found to increase locomotive mileage between periods when wheels had to be removed for hub liner renewals. Prior to the adoption of oil lubrication, solid hub liners depending upon grease lubrication were employed. Due to track curvature and other



On an eight-wheel switcher oil is distributed to 21 locations from an eight-feed lubricator

physical characteristics it was necessary on Santa Fe type locomotives to remove wheels for hub liner renewals at approximately 4,000 miles. This mileage has now been increased to approximately 70,000.

On other classes of locomotives, before the adoption of oil-lubricated floating hub liners, the average mileage

Oil line connection to the crown brass of a main driving box

between shoppings was much less than under present conditions. Table I shows a comparison between the years 1929 and 1936.

The mechanical lubricators supplying oil to all parts of the locomotives have their feeds regulated on a test rack located in the Sayre system shops and are then sealed. After sealing, the setting of the feeds is seldom disturbed between shoppings of the locomotive.

When engine No. 3137 was given Class 3 repairs in August, 1933, the driving journals were turned and rolled and the crown brasses were bored and rolled. The crown brasses were relieved to a distance of $\frac{5}{16}$ in. After four years of service, the journals, hub liners and crown brasses were found to be in excellent condition and after such minor repair work as tire turning, brake and spring-rigging repairs was done on the locomotive, the parts were returned to service. An application for a one-year extension on flues was granted.

Table I—Comparison of Mileages Between Shoppings

No. of Locomotives	Road Class	1929	1936
	SWITCHING		
97	L-5, L-5½ & N-2	55,071	110,884
	FREIGHT		
70	N-4 and N-5	46,806	115,480
20	N-6	35,000	76,500
40	R-1	25,717	86,023
50	K-5	48,957	121,207
	PASSENGER		
9	K-2½	69,767	182,009
14	K-3	112,500	165,216
15	K-4	76,444	173,437
12	K-6	198,975	275,477

Table II—Quantity of Dope Eliminated per Journal

Loco. Type	Location of Dope	Waste, Lb.	Oil, Pts.	Total, Lb.
0-8-0	Drivers	2.2	8.8	11.0
2-8-2	Engine truck	1.7	6.8	8.5
	Drivers	2.0	8.0	10.0
	Trailer truck	3.0	12.0	15.0

When the locomotive was unwheeled, measurements were taken of the wear on the various parts. The clearances between the toe of the crown brass and the journal just above the relief point were as follows:

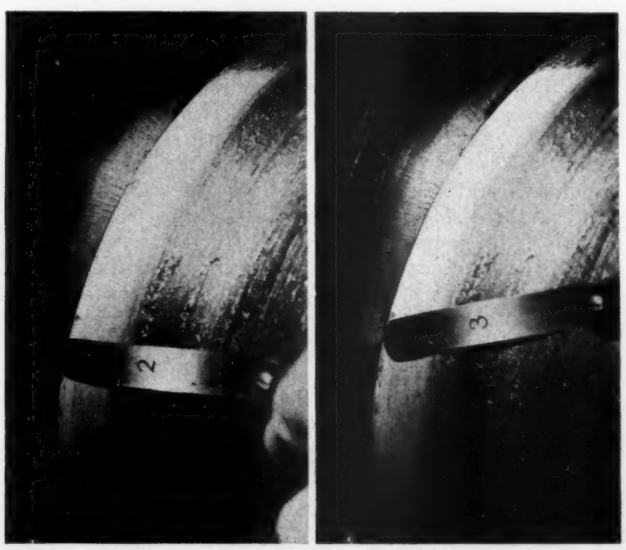
Wheel No.	Right Side in., max.	Left Side in., max.
1	.003	.002
2	.002	.003
3	.003	.002
4	.003	.002

The wear on the floating hub liners was as follows:

Wheel No.	Max. in.
1	.187
2	.125
3	.125
4	.187

The wear on the rocker boxes was $\frac{3}{32}$ in. in the right side and $\frac{1}{32}$ in. in the left side. An idea of the nature

The condition of crown and hub faces after 49 months service



The clearance between toe of brass and journal at Right No. 2 was .002 in.

Test rack in the Sayre, Pa., system shop where all mechanical lubricators are tested and sealed before being placed in service

and the extent of the work that was done on this locomotive during 49 months of service, from August, 1933 to September, 1937, is indicated by the following items taken from the actual work reports:

1933
Sept. 28—Tighten R-1 wedge bolt.
Oct. 18—Set up R and L-3 wedges.
Nov. 28—Set up L-4—3 wedges.
Dec. 13—Set up R-1 wedge.
L-3 wedges.

1934
Jan. 23—Close in right crosshead guide.
Set up wedges both sides.
Key up right back main rod brasses.
Feb. 20—Oil pipe coupling loose leading to rocker boxes, right side.
Mar. 7—Close in left crosshead guides.
Apr. 25—Set up R-4 wedges.
June 5—Oil pipe to right rocker box loose.
June 18—Set up wedges.
Oct. 9—Oil pipe to R-1 driving box leaks.
Oct. 23—Right forward eccentric oil pipe burst.

1935
Mar. 15—Oil leak at right steam chest where oil plug screws in.
Mar. 26—Left back driver box oil feed not working.
Apr. 29—Oil hose disconnected right front main eccentric strap.
June 25—Oil pipe leaking at lubricator.
July 11—Tighten oil hose to left back eccentric strap.
Aug. 22—R-1 driving box not getting enough oil.

1936
July 2—Tighten union nut on oil pipe leading to left front crown brass.
Nov. 17—Tighten oil leak at force feed terminal at air portion.
Nov. 24—Tighten oil hose connection L-2 driving box.

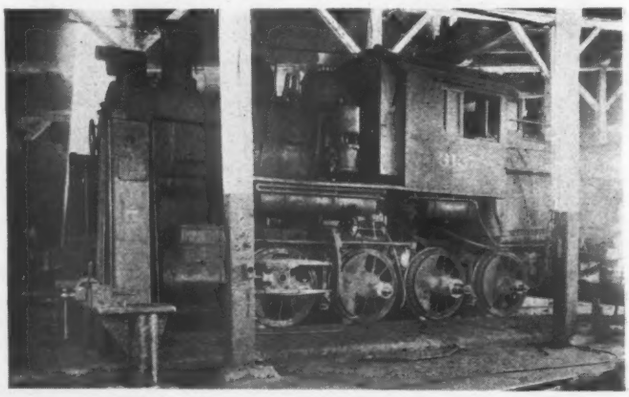
1937
June 8—Tighten oil pipe connection account leaking back of force-feed lubricator.
Aug. 26—Oil hose to left and right forward eccentric leaks.

These items represent all of the work that was performed on the locomotive pertaining to any parts oiled by this system of lubrication. The driving-box cellars on locomotive No. 3137 are equipped with secondary lubrication. Prior to the adoption of oil lubrication on the hub liners and journals as well as the valves, motion parts and crossheads, it was necessary to overhaul the motion work every eight months of active service. The main driving boxes required overhauling every six months, hub liners every six months, and the crossheads required relining on an average of once every six months. Experience with this lubrication system has indicated that it is possible to eliminate the swab holders on piston rods and valve stems as well as the oil cups on the guides, rocker boxes and eccentric straps. The mechanical lubricator is thoroughly cleaned out at monthly washout periods and at the same time the feeds are checked and tested and the oil lines blown out.

The employment of secondary lubrication makes the use of waste or "dope" unnecessary. Table II shows the quantity of "dope" per journal which is thereby eliminated.

Table III—Parts Lubricated on a Pacific Type Locomotive

Feed No.	Location	Dividers—No.	Dividers—Type	No. Flexible Connections	No. Points Lubricated
1	Trailer truck, journal and hub liner, right and left	1	2-way	3	4
2	Driving-box hub liners, right back	..	.....	1	2
3	Driving-box hub liners, right main	..	.....	1	2
4	Driving-box hub liners, right front	..	.....	1	2
5	Valve rod crosshead and engine truck center plate	2	2-way		
		1	3-way	..	7
6	Blank	..	.....	..	..
7	Blank	..	.....	..	..
8	Blank	..	.....	..	..
9	Frame shoes and wedges, No. 3 drivers	1	2-way	2	4
10	Frame shoes and wedges, No. 2 drivers	1	2-way	2	4
11	Frame shoes and wedges, No. 1 drivers	1	2-way	2	4
12	Blank	..	.....	..	..
13	Valve chamber, right side	..	.....	..	1
14	Cylinder, right side	..	.....	..	1
15	Stoker shaft bearing, rear	1	3-way	1	3
16	Stoker shaft, front end; radial buffer	1	4-way	1	4
17	Stoker engine	..	.....	..	1
18	Air-pump governor, drifting valve and generator governor	1	Atom.	..	3
19	Engine-truck journals and hub liners	1	4-way	4	4
20	Guides, top, sides and bottom, right and left	1	2-way		
		2	3-way	..	8
21	Driving box hub liners and hub, left back	..	.....	..	2
22	Driving-box hub liners and hub, left main	..	.....	..	2
23	Driving-box hub liners and hub, left front	..	.....	..	2
24	Link bearing, right and left	3	2-way	..	6
25	Valve chamber, left side	..	.....	..	1
26	Cylinder, left side	..	.....	..	1



Switcher No. 3137 ready for unwheeling at Perth Amboy, N. J.

Failures of

Locomotive Parts

By Fred H. Williams, M.Sc., F.R.S.A.

THERE are several causes for failures of locomotive axles in service. Stress-corrosion cracks, which develop into fatigue cracks, and fatigue cracks caused by a tool or other marks are so closely allied that it is extremely difficult to determine which may be primarily responsible for the failure. The writer is of the opinion that the life of a locomotive axle should be one million miles. This seems like a high figure, and yet it should be attainable. Main driving axles are removed from service when they make 300,000 miles. While some axles fail at a lower mileage, this has been fixed as a reasonable figure. If we could eliminate tool marks and stress-corrosion, the axles would be good for at least another 300,000 miles. This applies to both carbon steel and alloy steels, with slight exceptions.

Tool Marks a Matter of Controversy

The moment we mention tool marks we get into a controversy. Undoubtedly, however, they do cause failures and expensive ones, at that. We cannot afford to take chances.

Let us see what tool marks will do to a fatigue endurance test piece. Such a polished test piece may give 45,000 lb. endurance limit; that is the stress which will cause the test piece to fail at, say, ten million reversals. If, however, a slight tool mark is left on the test piece it will fail at 20,000 lb. stress, and probably at a much smaller number of reversals. In other words, the life of the test piece is cut in half by a fine tool mark. The same thing applies to the axle from which the test piece is taken. If, in addition to the tool marks, conditions are complicated by stress-corrosion, the test piece will, of course, fail at a still lower stress than where this combination does not exist.

Axles have failed after only 80,000 miles of service from stress-corrosion which has developed into fatigue cracks, or from tool marks which have done the same thing. Unfortunately the tool marks so affect the surface that, given an opportunity, corrosion will start much more rapidly than on a smooth surface. The tool marks also tend to concentrate the stresses.

Typical Fractures

The fracture of a main driving axle, which is typical of many such failures, is shown in Fig. 1. This failure was caused by a number of fatigue cracks starting on the surface of the wheel fit. The fatigue crack which caused the fracture started about one-half inch from the hub face and, as will be seen by the texture of the broken metal, extended very nearly across the section before the axle failed completely. The fatigue crack is represented by the more closely grained structure, while the final fracture is indicated by the coarser section at the lower left-hand side.

It will be noted that two of the fatigue cracks started to the left of the keyway and quite near each other. They were, however, at different planes and a close examination of the wheel fit surface indicated that they originated in two parallel tool marks (Fig. 3). The fracture also indicates that another fatigue crack started about one-half inch to the right of the keyway, as is indicated by the rings of progression of the fatigue crack. These three cracks continued to grow progressively and eventually united and finally developed to a point where they caused the failure of the axle. The steel was satisfactory, since it did not give way until the fatigue crack had extended to about 90 per cent of the area of the section. Incidentally, this indicates that the material was an alloy steel (nickel, in this case), since plain carbon steel would not ordinarily stand up so well under such conditions.

An enlargement of the fatigue cracks to the left of the keyway is shown in Fig. 2, the dark mark between them being caused by shadow, due to the fact that the two cracks were on different levels, starting from adjacent tool marks, somewhat less than 1/16 in. apart. An enlarged view of the surface of the wheel fit is shown in Fig. 3, clearly indicating the difference between these two planes. The tool marks which caused the fracture stand out quite clearly.

It may be contended that such machining is adequate since the surface of the axle is torn when the wheel center is pressed on. It must be remembered, however, that the torn surface lengthwise, is not as harmful as the circumferential tool marks. Some corrosion is apparent on the surface of the axle and doubtless this had its part in assisting in the development of the fatigue cracks. The axle in question failed at less than 300,000 miles.

Stress-Corrosion Cracks

Why does a tool mark influence the steel surface to corrosion and thus start the axle on its way to failure? In my opinion, because the tool tears the surface, and in so doing changes the normal potential between the grains; this tends to develop an electric current flow between these grains, and with the least moisture present, electrolysis results and corrosion starts. The smoother the surface and the less disturbance of the grain structure, the less possibility there is of corrosion, which means rust and pits, then stress-corrosion cracks, then fatigue cracks, and finally the complete failure of the axle or any other part of the locomotive which may be subjected to reverse stresses.

A mild heat treatment after the machining would, no doubt, remove the surface strains, but care must be taken to have the proper temperature applied to the part under treatment. Not only is it necessary to use care in machining the finishing cut, but the roughing cut should be free from excessive tears. Hogging the material off is dangerous, making it almost impossible to remove the effects by a finishing cut. I have seen a 12-in. axle so machined that the effect of the rough tool marks could be noted after the finishing cut had been made.

Another type of failure caused by tool marks and stress-corrosion is shown in Fig. 4. Looking at the top of the photograph it is apparent that the fatigue crack started from several nuclei, these several cracks uniting into the larger fatigue crack. As indicated in previous articles, these fatigue cracks start where special stresses concentrate on the surface in lines or spots, such as tool marks, tears in the metal, corrosion pits, or even inclusions in the steel. Conditions of service and the

FIG. 1

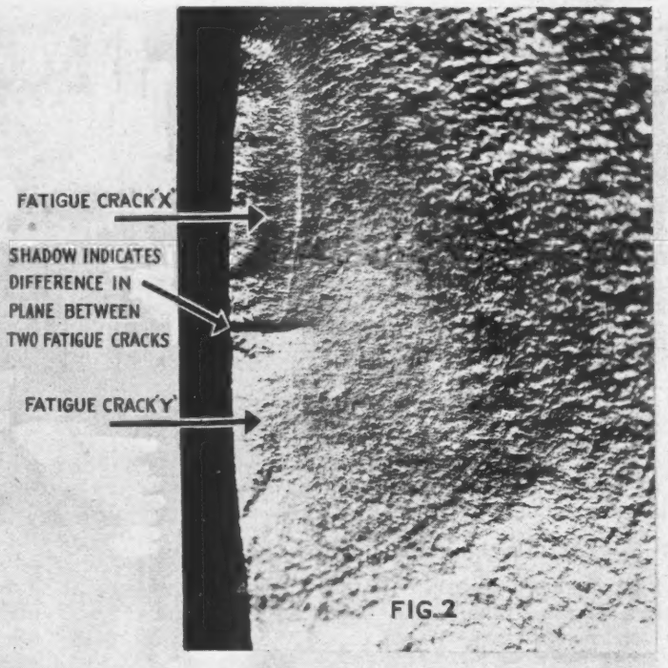


FIG. 2

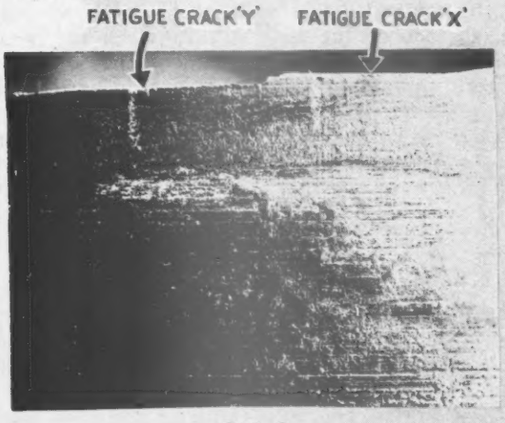


FIG. 3

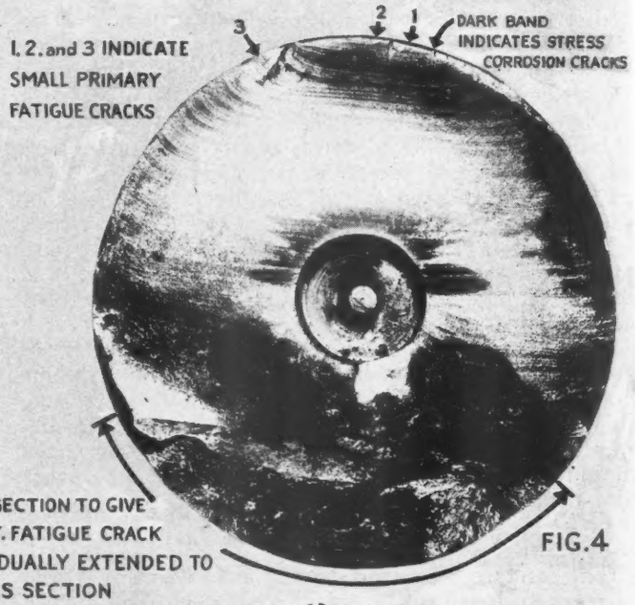

1, 2, and 3 INDICATE SMALL PRIMARY FATIGUE CRACKS
DARK BAND INDICATES STRESS CORROSION CRACKS
LAST SECTION TO GIVE WAY. FATIGUE CRACK GRADUALLY EXTENDED TO THIS SECTION

FIG. 4

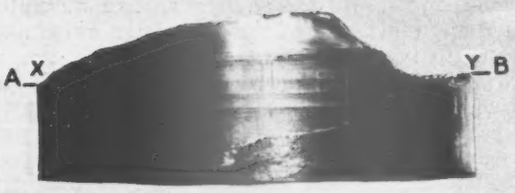


FIG. 5
FRACTURE STARTED ALONG LINE (A-B)

FIG. 6

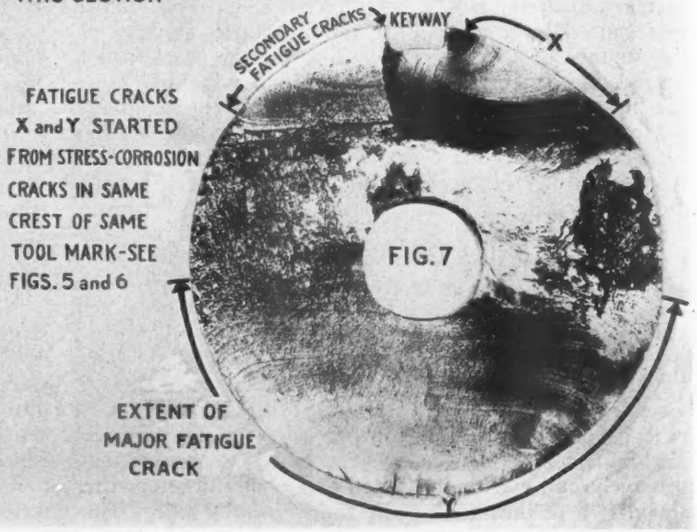

SECONDARY FATIGUE CRACKS
KEYWAY
X
FATIGUE CRACKS X and Y STARTED FROM STRESS-CORROSION CRACKS IN SAME CREST OF SAME TOOL MARK-SEE FIGS. 5 and 6
EXTENT OF MAJOR FATIGUE CRACK

FIG. 7

steel used naturally enter into the problem. This does not mean that you can secure steel that will resist the starting of fatigue cracks, but some steels can do so better than others. It will be noted from the finer texture of the break that the fatigue crack gradually extended over nearly 75 per cent of the area before the final fracture occurred. This would indicate that a good steel was used and that its heat treatment was satisfactory.

The finish on the wheel seat of another axle which failed at less than 300,000 miles, is shown in Figs. 5 and 6. Here we have a wide finishing cut and the surface in general seems to be smooth and satisfactory; indeed, it is the type that is recommended by some engineers and shop authorities. The fatigue crack in Fig. 4 started in the hollows of well defined cuts, but that for the axle shown in Figs. 5 and 6 originated not in the hollows of the cut, but at the crests.

Fig. 1—Cross-section of a main driving wheel axle which failed in service. Fig. 2—Enlargement of the section to the left of the keyway in Fig. 1. The shadow indicates difference in plane between the two fatigue cracks. Fig. 3—Enlarged view of the surface of the wheel fit of the axle, indicating clearly the two tool marks from which the fatigue cracks shown in Figs. 1 and 2 originated. Fig. 4—Cross-section of the main driving wheel axle which failed in service. Here corrosion, indicated by the dark band, combined with tool marks to start fatigue cracks. The break occurred in the wheel fit, about ½ in. from the hub face. Fig. 5—Side view of break which occurred in the wheel fit of a main driving axle. The crack started in the crest of the tool mark made by the finishing tool. Corrosion is indicated by the rubbed surface on the crest of the cut. Fig. 6—View of the other side of the break shown in Fig. 5. Fig. 7—Cross-section of the break shown in Figs. 5 and 6. The narrow black band at the bottom (indicating corrosion) was 1/16 in. deep and about 4½ in. long.

A cross-section of the fracture illustrated in Figs. 5 and 6 is shown in Fig. 7, and it will be noted that there are at least three fatigue cracks, one on either side of the keyway, and one on the opposite side of the section. Note the thin rim of dark at the bottom of the photograph and the frilled structure of the fracture before the smaller cracks unite into the larger fatigue crack. The narrow dark band which extends for about five inches in length of the circumference is a stress-corrosion crack, which started at the crest of the tool mark. Here, then, we have a combination of a rough surface and stress-corrosion, which is quite as destructive as the sharp machine tool cut, where the fatigue crack starts in the hollow.

An enlargement of a photograph of the machined surface of the wheel fit on this axle is shown in Fig. 8 and throws further light on the cause of the fracture. The finish here is so rough that it is difficult to pick out the crests and the hollows of the cuts. The latter are indicated by their rougher bands and close examination will enable one to pick out the crests in a close, partially cold worked surface. The smooth surface to the left is the journal which is smooth and polished.

Another type of failure on what many people would call a good finish for a wheel fit, is illustrated in Fig. 9, which shows the cross-section of a fracture of a main driving axle. It somewhat resembles the other fractures, except that fatigue cracks extended over nearly the full surface, or through almost the entire section before failure. This is a heat treated (quenched and drawn) carbon steel axle. The extent of the fatigue crack before the final fracture indicates good steel.

The main fatigue crack seems to be directly opposite the keyway and there are also two small fatigue cracks at the edge of the keyway. Close examination indicated,

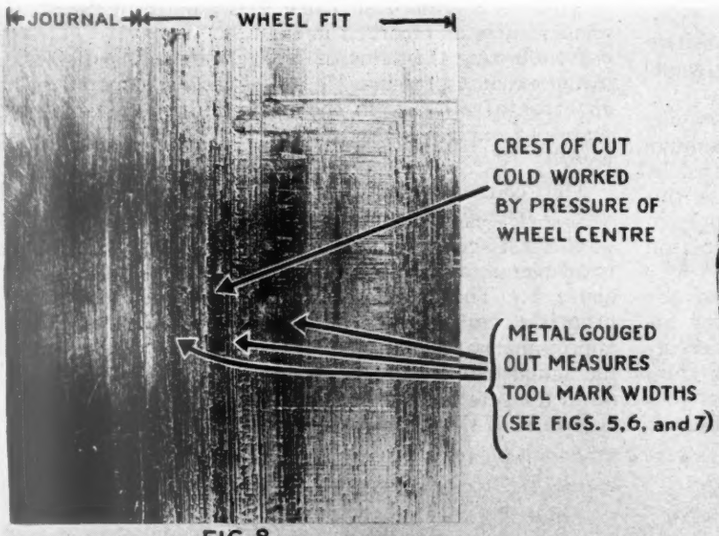

JOURNAL
WHEEL FIT
CREST OF CUT COLD WORKED BY PRESSURE OF WHEEL CENTRE
METAL GOUGED OUT MEASURES TOOL MARK WIDTHS (SEE FIGS. 5, 6, and 7)
FIG. 8

FIG. 9

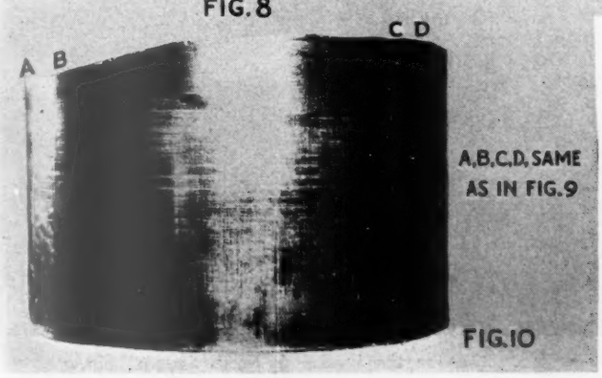


FIG. 10

Fig. 8—Enlarged photograph of what is known as a smooth surface on the wheel fit of an axle. For other views of the same axle see Figs. 5, 6 and 7. Fig. 9—Cross-section of fractured axle which failed because of fatigue crack starting ⅝ in. inside the wheel fit. A, C and D indicate separate fatigue cracks. B was due to a combination of the stress-corrosion cracks indicated by the arrows. Fig. 10—Finish of wheel fit of the main driving axle shown in Fig. 9.

however, that the fatigue cracks started at the wheel fit and a short distance from the edges of the keyway. Judging from the frills, we may conclude that the major fatigue crack was formed by a number of small cracks, indicating that stress-corrosion undoubtedly had considerable to do with the failure. The finish on this axle is shown in Fig. 10, indicating a broad finishing cut.

The Remedies

Even 12-in. axles have small surface stresses. Some tests, for instance, have shown that reversible stresses of about 3,000 lb. will cause a 12-in. axle to fail. The action of the movement of the wheel center on the axle starts corrosion, so that the stresses and corrosion are combined, and the cracks start without the heavy stresses which many people believe necessary to cause the failure of an axle of this size.

How can we remove these stresses? The use of cast-iron wheel centers would help a great deal if someone could develop such a wheel. The damping effects of cast iron relieve the stresses that attack the axle surfaces. As an example, passenger-car axles made of steel of lower physical properties than locomotive axles do not fail in the wheel fit where cast-iron wheel centers are used. The fact that we can now secure 60,000 lb. to 65,000 lb. tensile strength with the latest alloy cast irons would indicate possibilities in this direction.

Then, too, the practice of undercutting could be followed, as was advocated in previous articles which I have written for the *Railway Mechanical Engineer* on the failures of piston rods and crank pins. Undercutting will eliminate the causes of rust as well as the greater portion of the stresses that combine with corrosion and develop the stress-corrosion cracks. The undercutting should be .005 in. deep and from ¼ in. to ½ in. wide, about ½ in. inside the wheel center. The edges should have fillets and be rounded so that there will be no opportunity for the concentration of stresses. The finish of the undercutting should be smooth. Undercutting would seem to be well worth trial and experimentation.

Another possible remedy would be the metal spraying of a very thin depth, say .001 to .002 in. Aluminum would be a good metal to use and it has been tried by some with success and by others with failure, so this means that there is a good and a bad way to apply it. Having proved satisfactory to some there is no reason why it should not be well worth trying.

Why wait for failure? Why not use some of the methods which have given good results in similar installations? As indicated, these might include undercutting, metal spraying, smoother finishes and freedom from tears in the metal. Deep, or comparatively deep, tool marks should be eliminated. Machined surfaces such as shown in this article should be avoided, unless undercutting or metal spraying is used, and then a slight leeway in the smoothness of the finish can be allowed.

Reading Installs Streamline Train

(*Continued from page 4*)

streamlined with stainless and painted steel, the latter conforming to the lines of the coaches. An appearance of continuity of the sides of the coaches and tender has been effected by extending the sides of the latter beyond the tender end sill to enclose the rounded observation end of the forward car. A horizontal extension from the top of the tank produces a similar effect in the roof lines by enclosing the hooded portion over the end of the car. Louvers in the front of the locomotive shrouding near the top admit air which flows out of a port in the top of the shrouding just back of the stack to function as a smoke lifter. The estimated weight of the engine and tender is approximately 460,000 lb.

The Locomotive Front End

(*Continued from page 11*)

this discussion in all calculations involving V_2 and H_2.

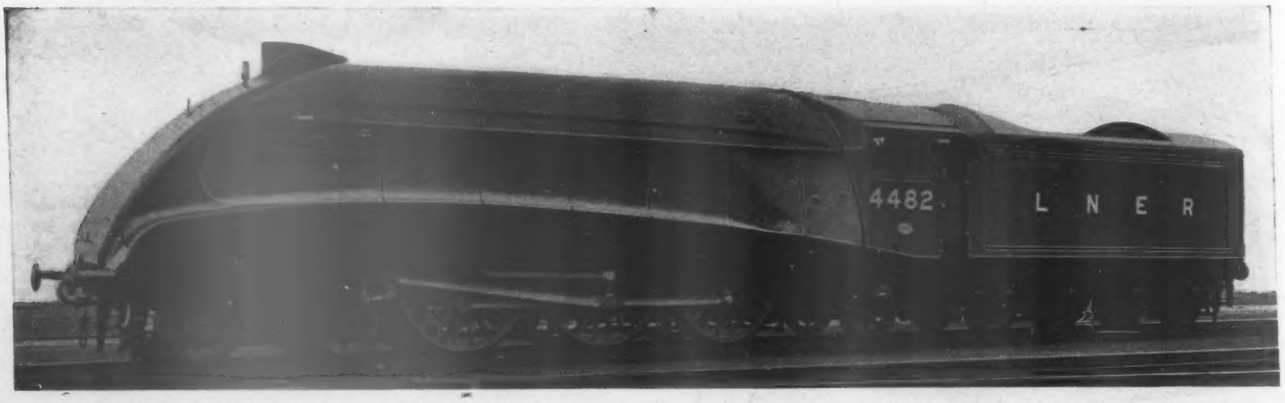
For calculating the consecutive values of M_t, shown in Fig. 4, tables were constructed similar to Table V, which applies to locomotive *A*; only sufficient values of M_t were calculated to establish the curve. The temperature t_1 given in column 4 of Table V is a mean of the actual temperatures as recorded in the test.

As affecting the value of ΔH, a misreading of 0.5 lb. in the exhaust pressure P_1 has about the same effect as an error of 40 deg. in the temperature t_1. This fact serves to explain some of the discrepancies in the test record.

The constancy of the relation between ΔP and $\sqrt{\Delta H}/V_2$ is shown by Fig. 15, which represents all of the tests cited for the eight locomotives. The curve is calculated on the basis of the temperature range shown above it. The actual test results are indicated by appropriate symbols. It will be seen that the curve closely approximates the test results, even though in some cases the actual temperature is 75 deg. F. above or below the mean temperature used in calculating the curve.

Part II of this article will appear in a subsequent issue.

* * *



The "Golden Eagle," the first of a new series of streamline express passenger locomotives on the London & North Eastern Railway

EDITORIALS

It Is To Smile!

According to the Railway Gazette of London, England, a controversy seems to be raging in the correspondence columns of a daily newspaper of that country, over the use of the words chimney or funnel "for the smoke uptake of a locomotive." The Railway Gazette points out that the word chimney has been used from the earliest days of the locomotive, dating back to 1804, when Richard Trevithick referred to the chimney of his "tramwaggon." On the other hand, the term locomotive chimney seems weak and effeminate to an American. It is never used in this country, even by non-railroaders. Smokestack seems far more appropriate when associated with our rugged and powerful locomotives, and then too, imagine how the railroad or locomotive "fan" would react to the term employed by our British cousins!

Tolerance

This is an unusual type of comment for a publication such as the *Railway Mechanical Engineer*. It is inspired by expressions received through the mail and otherwise, suggesting that we have a responsibility to discharge beyond that of discussing the technical problems in which we are primarily interested. In a way, it reflects an awakening interest on the part of individuals in a more intelligent participation in civic and political affairs.

The success of a democracy—a rule *of* the people, *for* the people, and *by* the people—can be gaged by the degree to which all of the members of the community work together for the common good. America has offered a unique opportunity for experimentation with representative democracy on a large scale. The United States, in particular, with its great natural resources and vast area, comparatively thinly populated, has thus far been unusually successful in its government and in improving the economic status of its citizens.

Made up as it is, however, of people coming from all parts of the world in large numbers over a long period, we have an unusual mixture of races, nationalities and religious creeds and beliefs within our borders. Conditions are still further complicated by the marked differences in climatic and economic conditions in various parts of the country. There seems to be a particularly strong tendency at the present time for the population of the different communities to divide into minority groups of various sorts and to use high pressure, press agenting methods in promoting their activities, which too frequently are of a selfish nature and sometimes with little regard for the general welfare. This intensifies class differences and engenders class strife.

Politicians, in campaigning, frequently play up to this in an impassioned manner—a rather disturbing factor to those who are sincerely interested in developing better understandings and higher ethical standards. Elective officers who would prefer to develop statesmanlike policies, often find themselves hampered by narrow sectionalism, and, it is to be feared, too frequently act under political pressure in the interests of a small minority group, rather than for those of the country or community at large.

The exce ingly trying period through which we are passing is such that each one of us must studiously strive to exercise a broad and intelligent viewpoint, else our democracy may go the way of others which have been replaced by dictatorships because of lack of interest and action on the part of intelligent citizens, coupled with abuses and high-handed methods on the part of those in political power.

New Shop Equipment Will Pay For Itself

A primary need in railroad shop equipment today is that of the replacement of a substantial proportion of the machine-tool inventory which, because of obsolescence due to age, is no longer able to meet the demand for volume production or accuracy of finish. More than 70 per cent of the machines in the average railroad shop are over 20 years old. When one considers the advances which have been made in the last 10 years alone in the art of metal cutting, almost anyone will concede that a 20-year-old machine is certainly to be classed as obsolete.

It is not necessary to indulge in any complicated mathematical calculations in order to appraise the cost of using obsolete machine tools. Let's take some actual figures in order to build an hypothetical case, apply some conservative estimates and compare the result with authentic service data. The result is sure to be surprising. In a certain locomotive repair shop there are 220 machine-tool units in the machine department. Of these, 67 per cent, or 150 machines, are over 20

years old. Assuming that the 150 machines comprising the group over 20 years of age are used 40 hours a week each, the wages paid to the machinists operating them amount to over $250,000, in a year. This total, incidentally, is $15,000 greater than before the recent increase in wages to shopmen. When that wage increase was granted it was necessary to curtail the hours worked by repair shops and consequently curtail the restoration of locomotive miles to road service. Experience indicates that the expense of machine-shop labor on these 150 obsolete machines could be reduced at least $65,000 a year by replacing them with modern units at an estimated capital outlay of from $475,000 to $500,000. This estimate of saving does not include reductions in the cost of machine-tool maintenance, reduced electric power consumption or economies resulting from a higher grade of workmanship.

In order that the reader will not be inclined to consider the above hypothetical case too much in the light of guesswork, a glance at facts may be worthwhile. A study recently made of 90 representative locomotive machining operations now being performed on machines over 20 years of age indicated that the time required could be reduced by an average of 42 per cent if the work were to be done on modern machines with modern tooling equipment. In the light of this figure, the estimate of $65,000 seems conservative enough.

Numerous installations made in the past three years indicate that one modern machine has enough greater productive capacity that it can take the place of from 1.35 to 2.50 machines of the 20- to 30-year-old type. By applying the minimum figure alone to the hypothetical shop, one arrives at the conclusion that 150 old machines could be replaced by 112 new ones. At 40 hours a week the labor cost of operating the 38 displaced machines amounts to over $65,000 a year, not to mention the saving of from $8,000 to $11,000 annually in repair costs due to their advanced age, and an additional estimated saving of about $3,700 a year in electric power.

Typical of the results which have been obtained as a result of machinery replacement programs is that of an eastern railroad which in 1935, planned a program for the retirement of 50 obsolete tools having an average age of 33 years and replacing them with 37 modern tools at a cost $227,000. It was estimated that, by operating the new machines 16 hours a day, 26 days a month, a saving of 26 per cent on the investment could be obtained. This would amount to $59,020 a year or $4,918 a month. The program was approved and the 37 machines were purchased and placed in operation by March, 1936. Due to business conditions the first full year's operation resulted in using this new equipment only 43 per cent of the planned two-shift operation. In spite of this, the savings effected at the end of 20 months' operation amounted to $86,478 or a total of 38 per cent on the investment. The monthly average was $4,324.

Another road recently retired 13 old machines in one group and replaced them with five new machines at a saving of 65 per cent in the cost of the parts produced in that department.

There are any number of cases where individual units of new shop equipment have paid for themselves in from one to two and one-half years but any lengthy presentation of such cases would add but little to the well-known fact that (1) new shop equipment is badly needed by the railroads; (2) that there should be little excuse for not buying it when it has demonstrated its ability to pay for itself, and (3) if the roads do not make plans to modernize facilities in the face of increasing costs they will inevitably find themselves in a position of being forced to choose between higher repair costs or deferred maintenance.

Welding Saves

One of the outstanding facts about shop-equipment orders in the railway field for 1937 is that three times as many electric-welding sets were purchased as compared with the purchases in 1929. This is indicative of the increased utilization of welding in car construction and equipment maintenance.

Welding is one of the two main factors in reducing the tare weight of freight and passenger cars, the other factor being the utilization of high-tensile alloy steels or strong aluminum alloys. In 1931, the Pullman Standard Car Manufacturing Company, built five welded 70-ton hopper cars of plain carbon steel which had a light weight of 45,900 lb.; this weight, compared with 50,200 lb. for the lightest riveted design of 70-ton hopper, represented a weight saving of 4,300 lb. through the use of welded fabrication alone.

In 1935, a number of welded cars were built in which high-tensile lightweight alloy steels were used extensively. All of these cars showed substantial tare-weight reductions as compared with riveted cars of plain carbon steel construction. One of these cars, a 50-ton 40-ft. box car built by Pullman, was fabricated by welding and showed one of the greatest weight savthetical shop, one arrives at the conclusion that 150 mately 10,000 lb. less than the 1932 A.A.R. standard 50-ton 40-ft. box car of plain carbon steel and riveted construction. It is interesting to note that this same weight reduction of 10,000 lb. has been effected in a 50-ton 40-ft. box car recently built by this same company to inside dimensions similar to those of the A.A.R. 1937 specifications, in which the tare weight and cubic capacity were increased to 45,300 lb. and 3,711 cu. ft., respectively, from 44,100 lb. and 3,311 cu. ft., respectively, for the A.A.R. 1932 design.

One of the noteworthy reductions in the weight of passenger cars is that of all-welded coaches built in the Milwaukee shops of the C.M.St.P.&P. This road built

52 all-welded steel coaches in 1934, employing plain carbon steel, which weighed 96,000 lb., as compared to 146,000 lb. for cars of conventional riveted construction using plain carbon steel. The weight reduction of 50,000 lb. was effected by a design adapted specifically for fabrication by welding. In 1936, when the C.M. St.P.&P. built nine train units for the Hiawatha, which were of the same conventional structural design as the cars built in 1934, a further weight reduction of approximately 10,000 lb. was effected by using Cor-Ten steel.

Welding is also being used more and more extensively in the railroad shops as a means for reducing maintenance expense of motive power and rolling stock. With the advent of improved electric-welding sets and designs of gas-welding equipment, as well as welding rods of higher physical properties and improvements in welding technique, the railroads have been able to show great savings in shop costs. For example, in 1937, one midwestern road showed a saving of $360,000 due directly to the use of electric welding.

Structural Defects In Freight Cars

Entirely aside from the effects of more or less unavoidable deferred maintenance, freight equipment now in use on American railroads is giving less efficient and satisfactory service than desirable, owing to certain features of design or construction which should be corrected wherever possible in present equipment and guarded against in all new designs. Responsible mechanical department officers welcome constructive suggestions for the improvement of equipment, from whatever source received, and consequently they are studying with interest a series of comments and suggestions, recently developed by the A.A.R. Freight Claims Division, as a result of an intensive study of specific car defects responsible for damage to various classes of commodities during shipment by rail.

As regards box car roofs, the report states that low carlines, some of which extend a foot or more below the inside surface of the roof, cause damage to furniture and other classes of freight. A common source of trouble is the shrinkage of siding resulting in comparatively large openings between siding boards with consequent admission of rain and dirt. In the case of single-sheathed cars, experience is said to indicate that the siding should be at least 1½ in. thick and not 1 in. as is now sometimes the case. It is suggested that all corrugated steel ends should be lined to prevent damage to freight, both the ends and the lining being constructed so as to permit moisture to drip and escape from behind the lining.

In connection with doors and doorways, the failure of car doors to fit flush against the decking all to frequently permits the entrance of dust and cinders. In some instances door strips are not flush with the lining. It is also important to have door posts and strips properly bevelled on both sides. One road has provided slots in steel door posts to permit the application of door protection, and apparently this practice should be made more general. Steel threshold plates on box cars having a provision for the safe application of loading bridges are a decided advantage and some roads have provided open slots for this purpose. The suggestion is advanced that many varieties of door and seal locks do not serve their purpose efficiently, and railway mechanical departments can help by endeavoring to eliminate the great variety of patent locks which are said to contribute to freight loss rather than preventing it.

In refrigerator cars, it is suggested that the roof and ceiling construction be designed so as positively to prevent cinders or insulation dust from working through and falling on the lading. Some refrigerator-car hatch covers are held open with a pin arrangement, these pins working out under the motion of the train and permitting the vents to close, thus creating a defective record. Refrigerator-car floors which extend under the bulkhead, with drip pans of insufficient width, permit melted ice to run in on the car floor. When floor-rack slats are held in position by screws, these frequently work out and cause damage to sacked goods and corrugated containers. Apparently slats should be bolted securely and placed longitudinal instead of crosswise. Obviously floor-rack fasteners in the side walls should be countersunk and all floor-rack slats bevelled.

In stock cars, low carlines present a hazard to horses by head injuries and it is felt that no carlines should extend below the inside surface of the roof, the necessary clearance for horses or mules being 8 ft. 7 in. The rearrangement of side boards is suggested to avoid injury to the hocks of horses and mules under present-day train speeds and vibration. Possibly at least one opening between the slats should be closed at a height of 18 in. to 22 in. Many stock cars are said to lack necessary means for applying partitions and the suggestion is advanced that consideration be given to the Con-Bur Brace Assembly developed by the A.A.R. Freight Container Bureau.

Another common complaint in stock cars is that bull-bar brackets are not flush with the door posts. Some types of doors with perpendicular slats in the metal frame may cause injury to animals crowding out of the car. This construction should presumably be altered to make the unloading of the car equally safe whether the door is fully or only partially open. Steel strips down the center of the floor, each 4½ in. wide and about 2 ft. apart, frequently cause animals to slip. Warped floors also are a potential hazard.

Due consideration of suggestions such as these by mechanical-department officers responsible for car conditions will doubtless be accompanied by appropriate action and do much to improve the standard of serviceability of freight equipment.

Gleanings *from the* Editor's Mail

The mails bring many interesting and pertinent comments to the Editor's desk during the course of a month. Here are a few that have strayed in during recent weeks.

The Keynote

The passing of the old days of a one-man shop is welcomed by everyone, but in the modern shop it is found no longer possible to be a successful executive by merely being a good mechanic. Co-operation is the keynote, and it is a fortunate superintendent who is able to get it.

Roundhouse Economies

How well all supervisors appreciate the suggestions made by Walt Wyre in his story in your November issue! More modern machinery is needed at division points; it is a fact that all foremen are racking their brains in the effort to secure time-saving machines.

A Big Customer

How many of your readers keep themselves informed on the great national importance of the vast network of railroads in this country, and by which we are employed? From whatever point of view we approach this problem, we cannot but be impressed. For instance, materials and supplies in 1936 cost the railroads $803,000,000. About 16 per cent of the total timber cut from our forests was purchased by the railroads; also about 23 per cent of the bituminous coal mined, and about 19 per cent of the fuel oil. The railroads also took about 17 per cent of the total iron and steel output of the United States. Truly, they represent one of the largest customers of the basic industries of our country.

Move Fast and Get Out of the Way

Has it ever occurred to you that the modern locomotive has saved the railroads large sums of money by postponing the requirement for second and third tracks and reducing the number of passing tracks. A train that gets over the road will leave clear tracks for other trains.

A Little Coaching Needed

You had another article in the November issue which is very good; that is, the one about Diesel-engine repairs on the Canadian National. I have noticed many times that men become intolerant of the supervision of the general officers, because it delays their work for the moment. The forms and reports used in this class of work show how valuable information can be obtained by requiring their use.

Some Challenging Questions

Several types of disk wheels have been developed. Have the anticipated improvements been realized—in greater strength, retaining rotundity, better balance and reduction of dynamic augment?

With high piston speeds never before experienced, together with high temperatures, the cylinder packing becomes a problem.

How are different roads going to meet the requirement of providing seating for head brakemen?

It appears an epidemic is being experienced with laminated boiler sheets, which no one as yet seems able to explain.

Considerable trouble is experienced with broken tires and heat checks and cracks in them; also developments are under way for improvements in brake shoes.

Considerable thought is being given to trucks that will contribute to the better riding of trains at high speed.

There seems to be a lack of authentic information as to the cost of operation and availability of Diesel equipment in mainline service.

Photo by Thomas T. Taber

An unusual coincidence—"The Empire Builder" and "The Fast Mail" of the Great Northern at Fargo, N. D., at the same time

THE READER'S PAGE

Failures in Crosshead and Piston-Rod Key Slots

To the Editor:

In many cases poor workmanship and improper machining methods on crossheads and piston rods for finishing key slots have been the cause of piston-rod failures. Often poor drilling is the main factor in causing failure. Again, piston rods fail because of the excessive use of the so-called engineer's soft hammer. The piston rods cannot be kept snug in the crosshead because they lack supporting metal at the small end when the slot is too near that end. Consequently, the incessant reversal of stresses and severe punishment with the hammer developed cracks at the small end that often leads to failure and rejection. The fact that such piston rods are placed in service indicates lack of proper understanding of the needs in exact locomotive maintenance, inadequate inspection, or a lack of funds to provide proper tools, such as milling machines and necessary jigs and fixtures.

Drilling of piston rods and crossheads on the average drill press shows that the shop lacks proper facilities for the work. No up-to-date master mechanic or shop superintendent would permit a machinist to drill a piston rod half way through, turn over, reset and finish the hole from the opposite side. The fact that the work was so finished shows most convincingly that the slots in crossheads were improperly located due to a lack of equipment. The big radial press is a poor makeshift for drilling crosshead-key slots.

Herewith are drawings that provide a method for machining key slots in piston rods and crosshead which, when properly applied, will eliminate failure of these parts at the key slot.

Figs. 1 and 2 show a crosshead mounted on a milling machine fixture. The first operation is to drill two holes in the proper relation to the finished key slot. The hole *A* is drilled ⅛ in. smaller than size, is enlarged by a reamer drill and then finished with a reamer. Hole *B* is drilled next and reamed. The piston rod, which is clamped in a vise, is now pushed to one end of the table as shown in Fig. 3. The spiral mill is then put through one of the holes in the crosshead and the slot is finished between the two reamed holes *A* and *B*. The face of *A* is relieved for the proper clearance. The jig is now set over at one end and face *B* is finished at the proper angle as shown in Fig. 3.

The crosshead is then taken off the milling machine, and the piston rod is pushed forward into position for milling. The mill is placed in one of the holes *A* or *B*, shown in Fig. 3, and the slot is milled. The face of hole B is relieved for the key clearance *C*.

Foreman.

Thermal Checks in Engine–Truck Wheels Eliminated

To the Editor:

On page 410 in the September, 1937, issue of the *Railway Mechanical Engineer*, your correspondent inquiries about the causes of thermal checks in the hubs of engine-truck wheels, and how can such checks be eliminated. He also wishes to know if the difficulty is peculiar to his railroad. Herewith are details of similar trouble noted on a mountain division of a northwestern road. The roadway was composed largely of grades and curves with short tangents in between. New locomotives after 21 days' service were returned to the main back shop, lifted from drivers, stripped of boxes, the hubs of drivers and truck wheels were faced for bronze liners, and crown brasses were refitted.

This costly and drastic procedure eliminated hot boxes and thermal checking. It was noted that the heating of driving-wheel and engine-truck boxes was caused by the heavy frictional contact between the hub and box and the lack of a steady flow of lubricant to the journals. The closure of crown brasses due to heating accentuated the trouble. The heavy side impact of the heated boxes against the heated hub faces caused the development and extension of cracks from the zones of thermal checking. However, it was noted that progressive cracking in and adjacent to zones of minor thermal checking was not as liable to produce wheel failure if the wheels had been relieved of internal stresses by heat treatment.

The necessity for heat treatment of car and engine-truck wheels arises from two principal sources: (1) The total relief of internal manufacturing stresses so that the metal of the finished wheel possesses its full potential strength, and (2) a modification of the structural chilled tread which will increase the resistance to impact failures and temperature gradients resulting from heavy brake-shoe applications and, in the case of engine-truck wheels, the lessening of thermal checking due to the severe side impact of the hub and truck box.

Frank Rattek

Three positions for milling the key slot in crossheads and piston rods

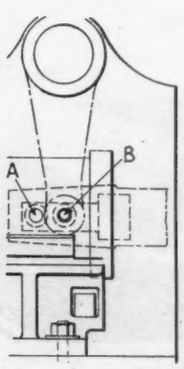


Fig. 1

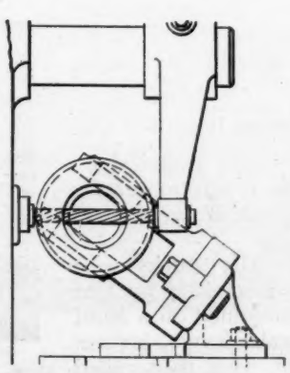


Fig. 2

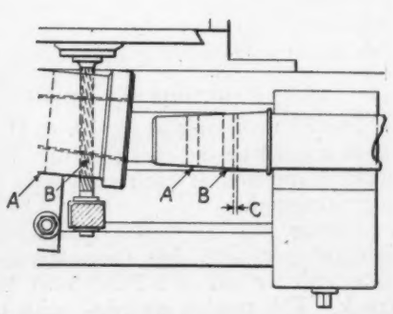
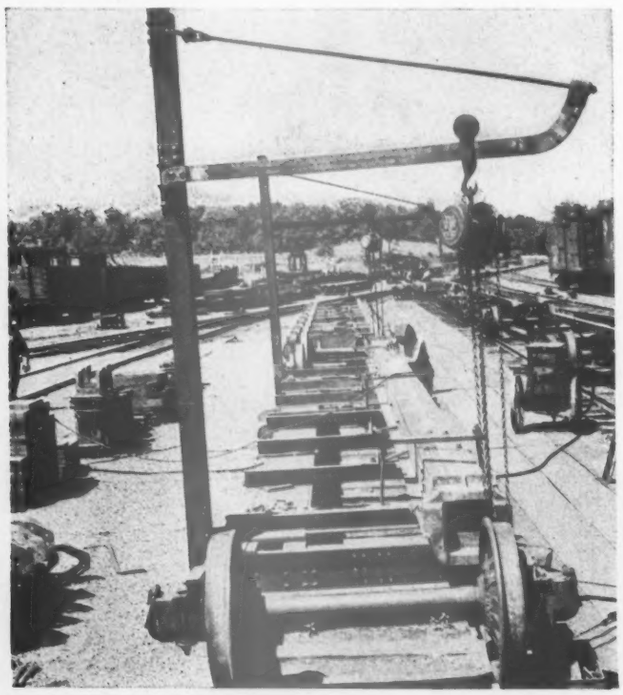


Fig. 3

With the Car Foremen and Inspectors

Car-Building Practice At the D. & H. Shops

The Delaware & Hudson car-building program for 1937 included the construction of 100 steel-sheathed box cars of 40 tons nominal capacity, weighing 41,000 lb. and having a cubical capacity of 3,318 cu. ft. Of this order, 75 cars of riveted and welded construction were built at the Green Island shops. The remaining 25 were built at the Oneonta shops; 10 of the cars built at Oneonta are of welded construction while the remaining 15 are welded with the exception of the ends, which are partially welded to the roofs and are riveted to the sides and end sills. The shop facilities for building the cars are quite different at the two shops, thereby requiring different movements for handling the materials during the various fabricating operations.



The welding jig at station 3 at Green Island—Trucks with center-sill sections arriving from station 2 are on the adjacent truck

The completed center sill being lowered to the underframe jig at station 4 at Green Island

Construction of Cars at Green Island

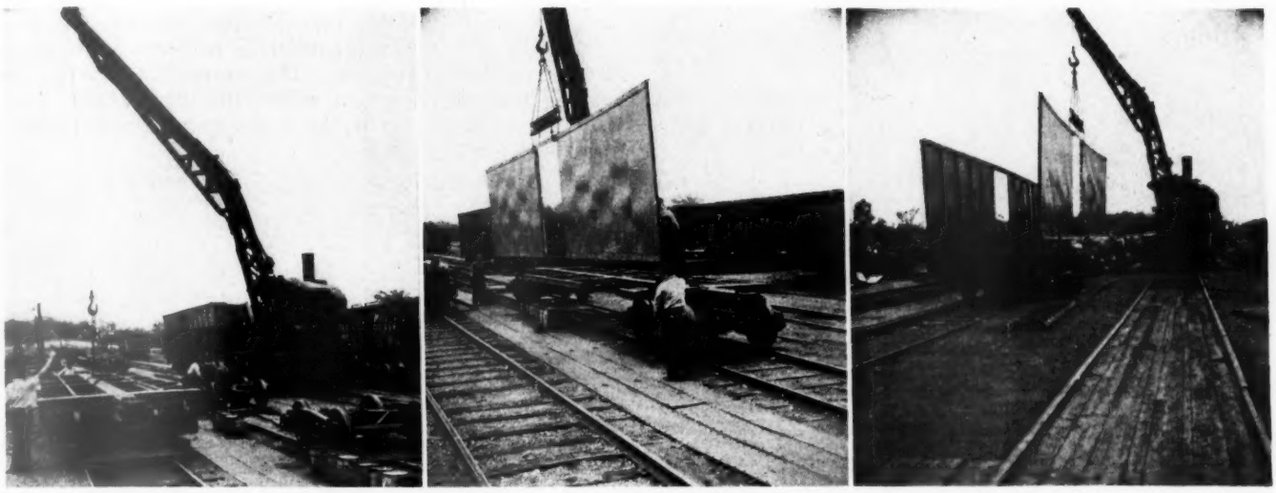
The 75 cars built at the D. & H. Green Island shops were erected by the spot system. The description of the work completed at each station is given in the following paragraphs:

Station No. 1—Truck Assembly—The trucks with integral cast-steel side frames were assembled by two men with the aid of a 2-ton hoist maintained on a hand truck. The trucks, complete with brake levers, bottom rods, AZee brake hanger suspensions, were then rolled to the assembly track.

Station No. 2—At this station a pair of trucks was placed on the assembly track about 30 ft. apart. Two Z-section A.A.R. center sills of Manten steel, weighing 31.3 lb. per ft., were lifted from storage by a tractor crane and placed on the trucks. The trucks and sills were then rolled down the assembly truck to station No. 3.

Station No. 3—An erecting crane, on a track adjacent to the assembly track, lifts the center-sill sections from the trucks to a center-sill welding jig. This erecting crane is a wreck crane with the boom extended tem-

Riveters completing the underframe in the jig at station 4 at the Green Island shops



Left: Transferring the underframe from station 4 to the trucks at station 5. Center and right: Applying the car sides at station 5 at Green Island

porarily to appropriate length. The swing of the boom is such that all the operations described at stations 3, 4 and 5 can be completed with a minimum of movement on the part of the crane. The sills were clamped in the welding jig bottom side up, after which the bolster center fillers, front and rear draft-gear stops, buffer castings and spacers were applied, fitted and riveted. The draft gears were then dropped into position and the sill was tack welded from the bottom side. The sill was then turned over, clamped into position, and continuously welded from end to end.

Station No. 4—The completed center sill was lifted by the crane from the center-sill jig and moved to an underframe jig on which had previously been placed the body-bolster center plates and body-bolster bottom cover plates. Bolster webs, crossbearer webs, and crossties were then applied and bolted in place preparatory to riveting. Three riveters from station No. 3, progressing with the work, riveted side-bearing reinforcement castings in between bolster webs. Body-bolster top cover plates and side-sill reinforcing channels were then bolted in place by one man working ahead of the riveting gang. The top cover plates for the body bolsters were then riveted.

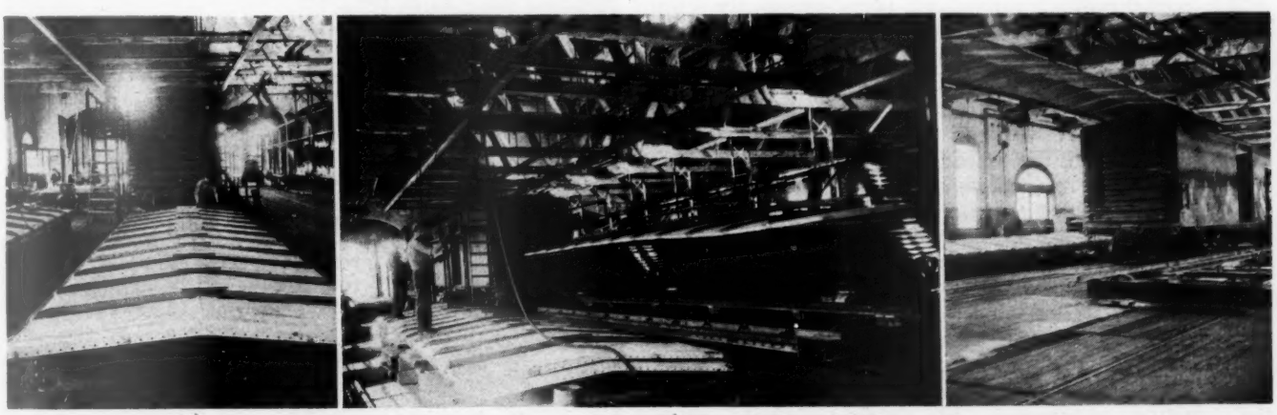
Station No. 5—The underframe was set on the trucks and one-piece sides were set and bolted in position.

Station No. 6—The cars, with the sides bolted and placed in position, were rolled into the shop where the ends were applied by a hoist affixed to the roof beams. The ends were of Dreadnaught design received in two sections and subsequently welded together in a jig. Safety appliance brackets were riveted, as required by I. C. C. safety rules. The ends were applied as explained, fitted, reamed and riveted. The couplers, uncoupling levers and Ajax hand brakes were also applied at this station.

Station No. 7—All roof work was done at station No. 7. The roof, of Chicago-Hutchins Dry-Loading design and received at the shop in sections were placed in a special jig, seam caps were applied, and the assembly was riveted. A special lifting jig was then bolted to the roof. The roof was lifted flush to the roof beams by means of two air hoists. The car was rolled under the roof, which was then lowered, bolted and riveted in position. Doors and door fixtures, AB brake and brake rigging were also applied at this station. The car was then sprayed with red lead.

Station No. 8—The car was rolled down the shop to station No. 8 where floors were applied and fastened with special car bolts, after which nailer strips and lining were applied to the sides and ends. The running boards were also laid out and applied at this station.

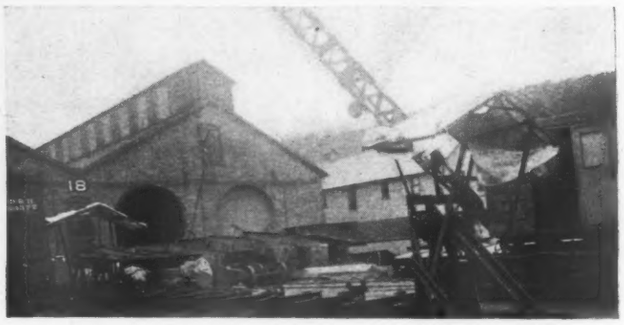
Station No. 9—The car was then removed to the paint track where is received two coats of Delaware & Hudson standard color paint, applied by spraying; the lining of the car was sprayed with Sipes enamel oil and the floor given a coat of Balcolac. The outside of the roof was sprayed with two coats of Valdura black after the inside



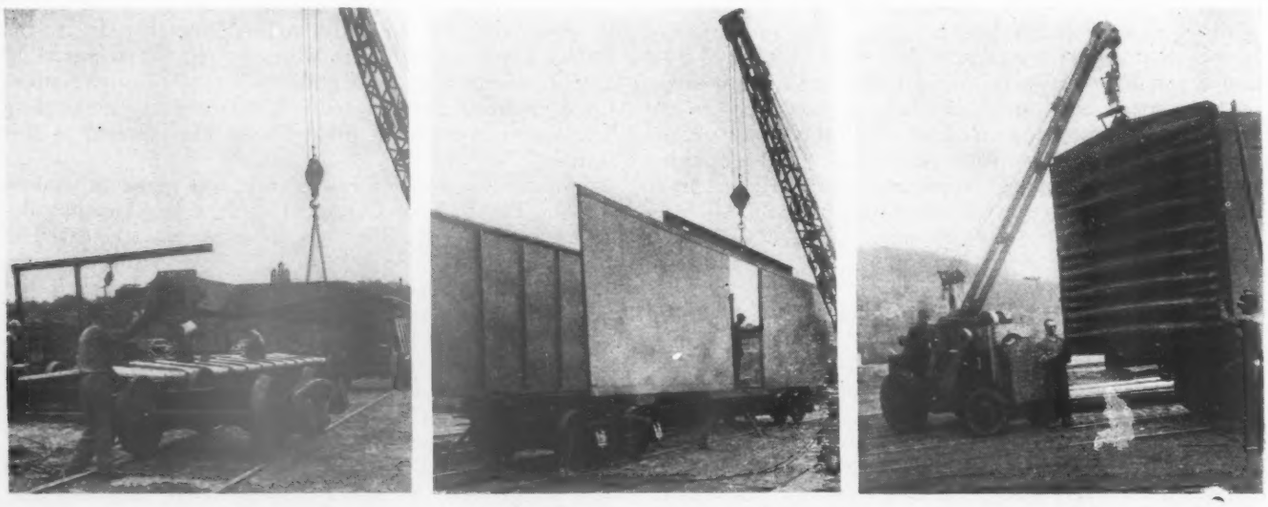
Station 7 at Green Island. Left: The completed roof and its jig. Center: Raising the roof from the jig. Right: The roof hoisted in position, and the car being moved beneath it

Station 8 at Green Island where floors, lining, running boards, and doors are applied

in a jig which included facilities for mounting the underframe on trunnions in order to perform all welding in a down or flat position. The sequence of operations was as follows: Z-section center sills of Man-ten steel were swung onto the jig by a Browning tractor crane,



The trunnion welding jig at the Oneonta shops with a completed underframe rotated to a horizontal position



Erecting scenes at the Oneonta shops. Left: Lowering the underframe under the trucks. The jig for assembling roofs shown in the background. Center: Applying the car sides. Right: Applying the Dreadnaught car ends

and outside had been sprayed with one coat of galvanized iron primer. The car was then stenciled by the spray method and turned over to the transportation department for revenue service.

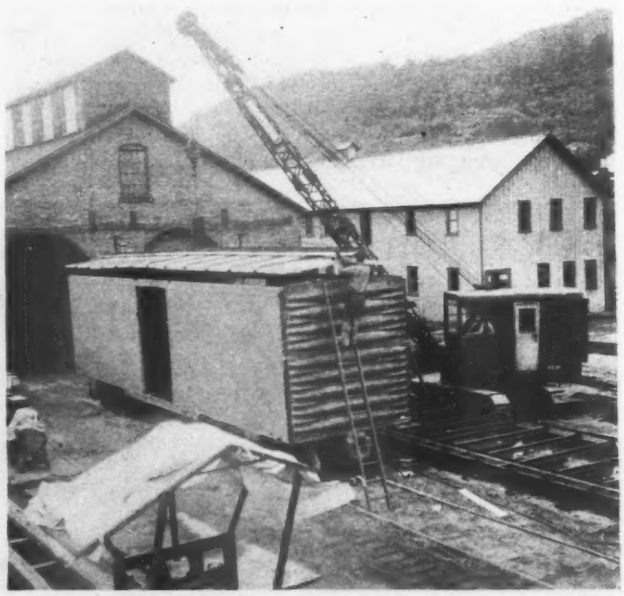
Construction of Cars at Oneonta

The cars built at Oneonta were erected at one centrally located position on the lead track outside the main car shop. Jigs were used for assembling the car ends, roof and underframe, the jigs being located adjacent to the erecting position. The parts assembled on the various jigs were moved directly to the car for assembly, or to storage if the work on the parts proceeded faster than that required for assembly.

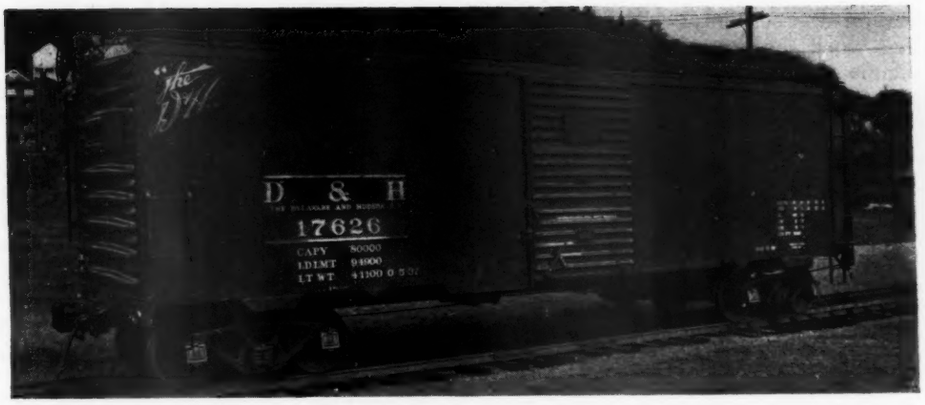
Dreadnaught car ends delivered to the shop in two sections, were welded together in a jig, after which running board, Wine ladders, brake step, Ajax hand-brake and hand-hold brackets were riveted in position.

The roof, of Chicago-Hutchins Dry-Lading design, were delivered to the shop in sections and assembled in a roof jig. These sections were applied to the jig together with the seam caps, after which the caps were riveted in position with a Chicago Pneumatic riveter. As the riveting progressed the running boards were measured, drilled and bolted into position.

The underframes of the cars were completely welded



Applying the car roof at Oneonta—the car is completed in the shop shown in the background



One of the completed 40-ton nominal capacity box cars built in the D. & H. shops

after which front and back draft-gear stops, buffer castings, center-sill spacers at crossties and cross bearers were welded to one of the Z-sections. The two Z-sections were then clamped down on the jig. The seam between the two Z-sill sections was then welded from the top for its entire length. The sills were then turned over and the other side of the draft-gear stops and buffer castings welded to the other Z-section. The coupler yokes and draft-gear were dropped into position while the sills were bottom side up, after which the bottom side of the draft-gear stops were welded. At the completion of this work, the draft-gear carrier irons were bolted in place.

The center sill was then tipped right side up for assembling the top and bottom body-bolster plates, webs, crossties, cross bearers and cross bearer cover plates, all these parts being welded in place. The underframe was mounted in the trunnion jig and rotated so that all remaining welding could be done in a down or flat position.

After the welding operations were completed, the underframe was picked up by the Browning tractor crane and set on the trucks which were brought from a truck-assembly station and placed on the assembly track.

The sides of the cars, of all-welded construction built by the Greenville Steel Car Company, were moved from storage and applied to the underframe by the Browning crawler crane. With the sides held temporarily in place, the ends were moved from storage or directly from the welding jig by a tractor crane, applied to the cars and bolted to the sides preparatory to final welding or riveting. The diagonal floor braces, Z-bar floor supports, and AB brake brackets were then welded in position, and the AB brake cylinder and reservoir bolted in place.

Ten of the order of 25 welded cars have the sides welded to the ends while the remaining 15 cars have the sides riveted to the ends. The brake-lever guides and brake-lever fulcrums were then applied. Meanwhile the door track, stops and Youngstown steel door with Camel fixtures were applied.

The roof was then lifted from storage, or directly from roof jig, by the Browning tractor crane and set in position. It was fitted, the seam caps riveted, and welded to the Z-bar side plates at the sides and the roof end sheets partially welded to the ends. Finally, when this work was completed, all joints were welded.

After these operations, the car was run onto the paint track where it was cleaned and sprayed with red lead. A heavy coat of Continental cement was applied for a height of 2 ft. at the inside ends and sides of the cars to prevent corrosion.

The cars were then run into the shop where the floor, end and side lining were applied. The air-brake equipment was then applied. The car was then removed to the paint track where all painting, similar to that explained for the work at the Green Island shops, was applied.

The Lubrication of Railroad Equipment*

By L. Grisbaum†

The problems of railroad journal lubrication have been with us a long time, and through years of constant contact with them, a vast store of knowledge and experience has been accumulated. Through research and study promoted by the company with which the writer is associated facts were proven or developed and segregated from opinions and, by an orderly arrangement of the factual knowledge so developed, we believe that much has been done to raise journal lubrication to the same high plane as other major lubricating problems. At least, many service applications strongly indicate that journal assemblies can be set up and operated with reasonable assurance of continued and uninterrupted service.

In evaluating the great amount of work and study we have done in the past few years, I believe our research to be more recreative than creative. There are close to 21 million journal-box assemblies in operation on our railroads. We felt that any development to be economically sound and acceptable must use the present equipment as the foundation for improvement. Our work, therefore, has been chiefly concerned with attempting to ascertain those things that are causing trouble from design, operation and practice; to find ways of correcting where possible the faults of operation; and to improve where necessary the mechanical weaknesses without interfering with the basic design or interchangeabilty.

Unfortunately, there is no one or even several corrective factors that will solve our problem. Our troubles originate in many ways and from many causes: The mechanical factor is our greatest concern, operation adds its share and lubrication difficulties are of some consequence.

We are told: "The intrinsic and economic worth of anything is its usage value." No one can question the intrinsic worth of the car-axle assembly. At the eighth annual convention of the Master Car Builders' Association held in Cincinnati, Ohio, in 1874, the present design was accepted as standard, and since that time there has been but a few minor changes or improvements, most of which have been metallurgical. The

* Presented at a meeting of the Eastern Car Foreman's Association held at the Engineering Societies Building, New York, November 16, 1937.

† Railway Service and Supply Corporation, Indianapolis, Ind.

design was certainly well conceived and executed, for it has stood the test of years of severe service. Its economic worth, however, is subject to debate chiefly because, in my opinion, it has been abused in practice. When the design was made, 62 years ago, the maximum size journal was 3¼ in. by 7 in. Today 7-in. by 14-in. journals are not uncommon. As loads were increased requiring larger journals no new design was incorporated; instead, all parts of the assembly were simply stepped up by comparison. With heavier loads came longer cars, higher speeds, longer trains, improved brakes, resulting in more rapid deceleration, and many other contributing influences. With all these increased demands of operation our permissible tolerances remain the same, or were from time to time made more liberal. When we had smaller equipment, a great many of the practices that are causing trouble today were not vital. Excess lateral was not as disturbing an influence, loads and speed were not as conducive to temperature influence on the deformation of the bearing with its effect of load concentration, and the demands of operation itself were not as exacting.

Cost of Bearings and Lubrication

Most mechanical men are more concerned with keeping equipment running with as few failures as possible than they are with the economy of operation. We have made miles per hot boxes our operating bible. If maintenance costs were made a definite part of the lubrication accounting picture, as is true in industrial lubrication, I feel that we would have far less replacement of defective parts and certainly fewer failures. The direct cost of lubricating materials and the labor of applying and handling is in excess of $15,000,000, annually. To arrive at the relative operating significance of lubricating cost, we should add to the above cost the cost of bearings and all other items contained in the indirect cost of lubrication, which those familiar with the cost of locomotive and car repairs will readily recognize as a figure several times that of the direct cost of lubrication.

Following is a statistical example illustrating the possibilities of economy in indirect lubrication costs. The Copper and Brass Research Association from its survey of the bearing and bushing industry estimated that there are 260,000 tons of bearing bronze in locomotives and car journal bearings on our railroads, and that the annual turnover amounts to 70,500 tons, of which 80 per cent or 56,225 tons are freight car bearings. On a basis of a 5½ in. by 10-in. journal bearing containing approximately 20 lb. of bronze, this means that the removal and re-application of approximately 5,500,000 journal bearings annually or over 2.5 bearings per car. To check this figure we made a survey of our own for a period of three years on two Class I eastern railroads and found that on a basis of 10,000 car miles one road used an average of from 2.6 to 2.96 bearings per car, and the other road used from 1.97 to 2.54 bearings per car.

We all know that a very small percentage of these bearings were involved in actual failure and further that 5 per cent would be a conservative estimate of the number of bearings actually worn through the linings. The great majority were removed for cracked and broken brass or linings, loose linings and end wear. Some defects and failures naturally resulted from faulty bearings, but the majority were removed due to mechanical conditions of construction and operation. To me, this figure of less than 5,000 car miles per bearing applied represents considerable economic waste, particularly when there are many bearings in service producing many times this number of miles in a very satisfactory manner.

While journal bearings, including the labor costs involved to handle and apply, is the major expense of indirect lubrication cost, cut journals caused by faulty lubrication or mechanical defect is another item of some consequence. On one railroad operating 34,000 freight cars, 12,000 pairs of wheels were removed in running repairs in 1934. Of this number 29.7 per cent were removed for cut journals.

The foregoing illustrations are used to point out forcibly that failures, regardless of how reported, are a poor criterion of operating efficiency and are certainly misleading as a measure of lubrication economy. When we have reduced the indirect costs of lubrication by eliminating defects, failures will automatically be reduced.

We all know that the design of the journal assembly is not perfect, particularly for present-day operation, and that we can normally anticipate some trouble from its deficiencies; however, by taking adequate advantage of the technological developments available, a great deal of the trouble can be eliminated. Again, by correcting erroneous practices coupled with intelligent supervision and inspection, further savings are possible.

We all know that indirect self-lubrication falls short of complete dependability. Much has been learned in the past few years about oil and waste performance; however its weakness as a lubricating medium has been greatly minimized. Lubrication can be the least of our worries in journal operation; in fact, if the mechanical phase of our problem was as well advanced and as generally accepted as the available lubricating practice, we would be close to our goal of placing car lubrication in step with other major lubrication problems.

A Universal Problem

Let me remind you that car-journal lubrication is a universal problem and must be treated as such. The benefits of uniformity in journal lubrication cannot be over estimated. Unfortunately, the maximum good cannot accrue as long as a number of roads insist on using materials and following practices that are definitely not suited to the best interests of general improvement. If the rules governing lubrication and operation of interchange equipment are not adequate to serve their purpose, let them be changed. There is no justification for us to be critical of the equipment that has served us so well. There is plenty of evidence for justifiable self-criticism, both as individuals and organizations, for neglecting to advance the efficiency of the journal assembly in keeping with the many other railroad developments. The actual situation in regard to railroad-journal operation was summed up by the president of a large roller-bearing manufacturing company, who stated:

"I admit frankly, from a contact of 22 years with the antifriction-bearing business, that if the plain bearing had been developed by specialists and always kept in the hands of its friends, our problem might not have been so easy as it has been.

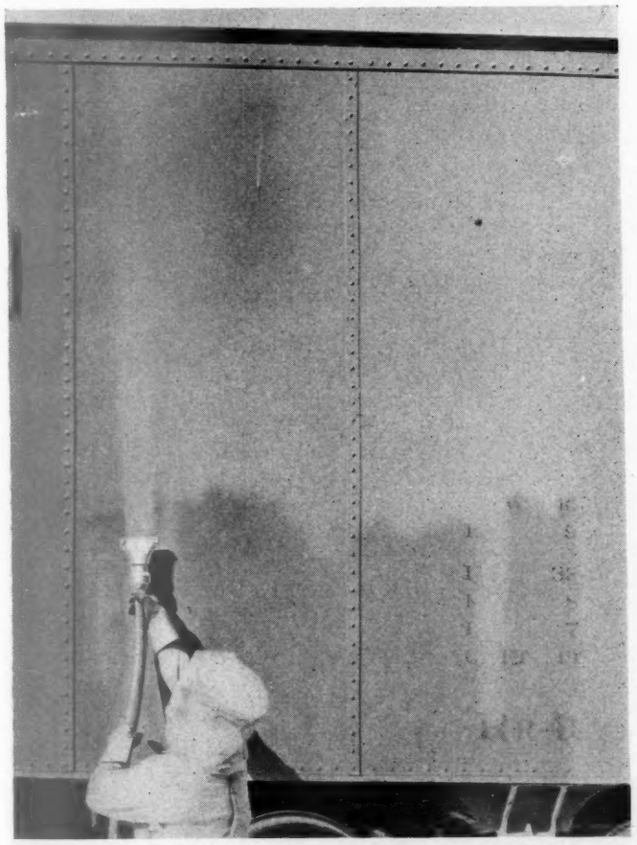
"That, I think, is an excellent example of the axiom: 'What is everybody's business is nobody's business.' Every one has assumed that he knew everything that was to be known about a plain bearing, and the result has been that there have been too many wrong principles in the design, manufacture, and application of plain bearings.

"The antifriction bearing has been developed by its friends, and through that concentration of effort the sum total of all the information which has been available has been disseminated, I think usually wisely, for the benefit of the user."

I admit that the car-journal bearing and all other parts in juxtaposition to it is the business of a lot of people. I refuse to believe, however, that the mechanical railroad officials will not take the responsibility for making the journal parts a serious portion of their business. There has been a lot of concentrated effort expended on the friction journal bearing since the above quotation was first made, and the information resulting from this effort is available to you. We have found a true bill in the indictment that there has been too many wrong principles in design, manufacture and application of the plain journal bearing, and have succeeded to an encouraging degree in correcting a number of the causes for this opinion. Not only was it possible to aid lubrication greatly by a modification in design of the plain bearings, but by minor refinements in manufacturing decided mechanical advantages were also obtained.

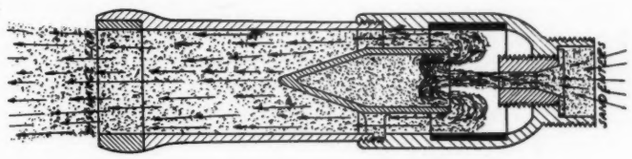
Sand Blast Gun With Flat-Mouthed Orifice

A new sand blast gun, now being manufactured by the Michiana Products Corporation, Michigan City, Ind., incorporates features of design and principle said to produce better surfaces for painting and finishing wood and steel in much less time and without injury to the surfaces of the materials. Exclusive license agreement for the manufacture and sale of this gun has been made with W. Schultz, shop superintendent, Atchison, Topeka & Santa Fe, Wichita, Kan., who is the inventor. The gun has been employed for cleaning wood refrigerator and steel-sheathed cars preparatory for refinishing, for several years.



Michiana flat-nozzle sand gun used to prepare the surface for repainting a steel-sheathed railway car

This gun, as shown in the drawing, has a chamber in



Sketch showing longitudinal section and principle of the Michiana sand gun

which the sand meets a baffle which sets up a whirling motion reducing the sand particles and increasing the number of cutting edges. Sand is delivered under 80 to 100 lb. air pressure through a flattened orifice fitted with abrasive-resistant alloy-steel lips. The result is a flat stream of sand expelled under uniform pressure. It is said that this design permits the use of lower cost sand, removes grime, grease and old finishes faster, and reduces buckling to a minimum on light materials without cutting or pitting the surfaces. Micro-photographs are said to show a smooth, clean surface.

Decisions of Arbitration Cases

(The Arbitration Committee of the A.A.R. Mechanical Division is called upon to render decisions on a large number of questions and controversies which are submitted from time to time. As these matters are of interest not only to railroad officers but also to car inspectors and others, the Railway Mechanical Engineer will print abstracts of decisions as rendered.)

Tank Shifted on Car Equipped With Cradle-Casting Center Anchorage

On September 19, 1935, the Grand Trunk delivered to the Pere Marquette at Muskegon, Mich., an empty tank car owned by the Keith Railway Equipment Company, which was damaged as follows: Left steel center-sill channel bent down 5/8 in. and bent out 1¾ in. for a length of 5 ft. in the center of the car; right steel center-sill channel bent out ¼ in. in three places; tank anchor casting on tank bent, A and B ends; tank bottom sheet bent, A and B ends; tank anchor casting on center sills broken, A end; longitudinal tank supports, 3¾ in. by 6 in. by 6 ft., broken on A end; and horizontal tank support, 5½ in. by 14 in. by 40 in., broken on A end. On October 8 the Pere Marquette sent to the car owners, a joint inspection, and estimated the cost of repairs at $125 plus the cost of one anchor casting from the car owner. The car owner ordered the car to its home shops for repairs and inspection and, after arrival, requested another joint inspection which was made on November 5 by the Pere Marquette and the Keith Railway Equipment Company; the same defects were noted as before. The owner contended that the damage to the car would be impossible in ordinary handling, and that, according to Rule 44, the Pere Marquette should furnish a statement showing the circumstances under which the damage occurred in order to establish responsibility of the car owners for repairs. Under note of Section 6 of Rule 44, tank shifting and damage resulting from tank shifting on cars equipped with cradle-casting center anchorage is the owner's responsibility. However, in this case the

owner contended the damage was done prior to the shifting of the tank. To substantiate its contention, the car owner quoted from the report of the Pere Marquette: "One steel center sill bent out 1¾ in. and bent down ⅝ in., which caused the breakage of the tank anchor casting." The Pere Marquette contended that the car was neither derailed, cornered, sideswiped nor otherwise damaged, according to Rule 32, on the Pere Marquette. An investigation of the car's movement over the G. T. and the C. M. St. P. & P., which also handled it between Muskegon and Milwaukee, likewise showed that it was not damaged, as classified under Rule 32, on their rails. The Pere Marquette maintained that the extent of damage to the car did not warrant a statement being furnished to the car owner under Rule 44 because the sills were not bent in excess of 2½ in., the greatest deflection being 1¾ in. on one sill, and that the owner was responsible.

In a decision rendered November 12, 1936, the Arbitration Committee stated that: "The shifting of the tank on its underframe in conjunction with damage to the cradle casting center anchorage and deflection in center sills, is owner's defects per second note under Item (6) of Rule 44 and does not require that a statement of circumstance be furnished to car owner. The evidence does not indicate that the car was subjected to any unfair usage conditions under Rule 32. The contention of the Pere Marquette is sustained."—*Case No. 1752, Keith Railway Equipment Company versus Pere Marquette.*

Questions and Answers On the AB Brake

Operation of the Equipment (Continued)

233—*Q.—What movement occurs in the service portion?* A.—When the brake-pipe pressure becomes slightly greater than the auxiliary-reservoir pressure, the service piston and slide valve are moved to either retarded-recharge or full-release position and the brake will be released and reservoirs recharged as previously described.

234—*Q.—When do the emergency piston and the slide valve assume charging position?* A.—The quick-action chamber is being charged through the charging choke, and the return spring will move the piston and the slide valve from accelerated release to charging position as soon as the air pressures on both sides of the emergency piston become substantially equal.

235—*Q.—Is communication then open between the brake cylinder and the brake pipe?* A.—No. The movement of the emergency slide valve blanks the port in its seat, thereby cutting off communication.

236—*Q.—Under what other conditions may the valve assume accelerated release position?* A.—The emergency piston and slide valve may assume this position on head-end cars when recharging.

237—*Q.—Will this have any effect?* A.—Not at this time.

238—*Q.—Why not?* A.—The brake-pipe pressure will be sufficiently higher than the brake-cylinder pressure to prevent unseating of the accelerated release checks.

General

239—*Q.—When manually releasing an individual brake by means of the duplex release valve, on the service portion, with the brake pipe charged, how should the release-valve handle be operated?* A.—Pull the handle only far enough to open the auxiliary check valve.

240—*Q.—How long should the check be kept open?* A.—Only until the brake-cylinder exhaust is heard starting.

241—*Q.—With no air in the brake pipe, how should the release-valve handle be operated?* A.—Drain both auxiliary and emergency reservoirs by pulling the handle its full travel.

242—*Q.—How long should the handle be held in this position?* A.—Until all the air is drained.

Combination Brush And Water Spray

The illustrated combination brush and water spray used for cleaning passenger cars has a tubular handle which it attached to the hose, and water flows up the handle and out of the center of the brush-head. The brush was designed to effect a saving in car-cleaning time inasmuch as the three operations of wetting, brushing, and rinsing are done without interruption. A continuous flood-wash-rinse action quickly removes dirt without harming the finish. In addition to this saving in labor, the spray brush offers an economy of water, inasmuch as the water coming from the brush-head is always in use on the surface of the car. An angle cock at the lower end of the aluminum-tube handle permits control of the water flow. Moreover, the fact that a constant flow of water is under the brush at all times lessens wear on the finish of the car. On the other hand, when the brush and hose are separate, workmen sometimes carelessly scrub dry portions of the surface, damaging the finish.

This product, called the Imperial spray brush, is now used by many leading railroads, including the Illinois Central; Atchison, Topeka and Santa Fe; Chicago, Burlington & Quincy; Chicago, Milwaukee, St. Paul & Pacific; Chicago, Rock Island & Pacific; Great Northern; Norfolk & Southern; and the Bangor & Aroostook. It is made by the Wilson Imperial Company, Newark, N. J.

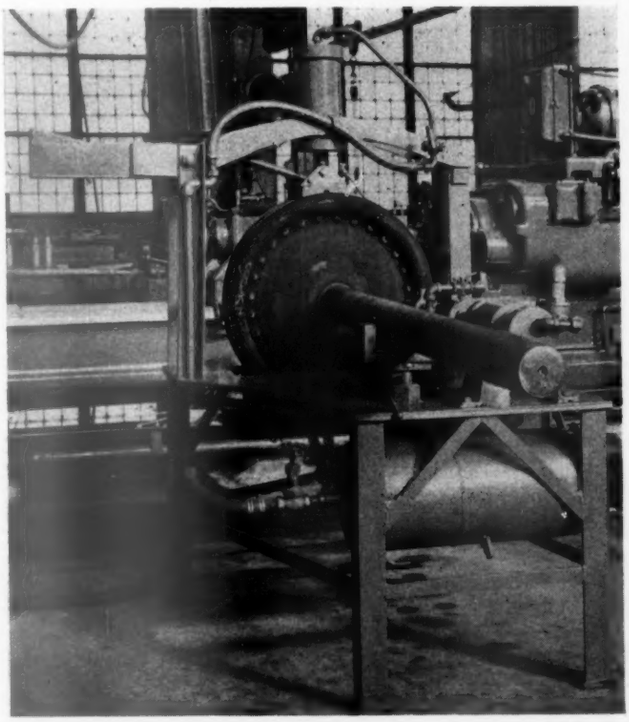
Imperial spray brush features flood-wash-rinse action

IN THE BACK SHOP AND ENGINEHOUSE

Three Shop Devices At Danville

Three devices which greatly expedite the work at the Danville, Ill., shops of the Chicago & Eastern Illinois are shown in the illustrations, including a piston bull-ring riveting machine, an electric boring bar drive and a lagging-mixing machine.

For riveting piston bull rings, the compact and efficient tool shown in the first two illustrations is used. It consists simply of a steel framework and table designed to support the piston on two rollers, a pneumatic clamping device to hold the piston in any desired position and two mechanically-supported air hammers, one of which applies the rivet and backs it up on one side of the piston, while the hammer on the other side forms the head.



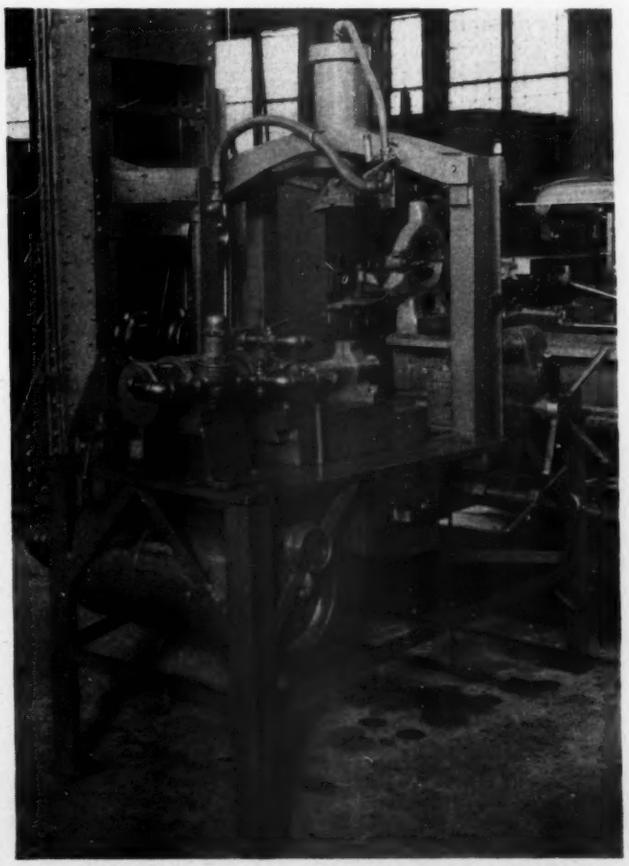
Piston bull-ring riveting machine with piston in place

Referring to the illustrations, the general construction of the machine will be apparent. The table top, made of ¾-in. boiler steel, is 60 in. long by 42 in. wide at the rear and 26 in. wide at the front, mounted on 3-in. angle-iron legs, 32 in. above the shop floor. The overall height of the machine from the top of the clamping cylinder to the shop floor is 76 in. A recess is cut in the rear of the table plate to receive the piston which rests on two 4-in. rollers capable of being drawn together or separated by means of a hand wheel on the front of the machine, thus making possible accurate adjustments of the piston height. The piston rod is supported near the center on a copper-lined bracket which is also adjustable for height by means of thread and nut arrangement.

After the piston has been elevated and rotated to the proper position for riveting, air is admitted to the cylinder at the top of the machine which forces a brake-lined shoe against the upper part of the piston and holds it firmly in position during the riveting operation. This holding piston, which has a 5-in. diameter and 10-in. stroke, is mounted in a light but rigid framework counterweighted and pivoted at the left vertical support so that it can be swung upward out of the way while the piston is being applied to or removed from the machine.

Referring to the view of the machine before application of the piston, the air-hammer operating parts are clearly shown. Each air hammer is rigidly mounted in an old lathe crossway which slides in a suitable block firmly secured to the table plate. The V-block and air hammer at the front of the machine are moved forward and backward by means of the small air cylinder illustrated. The piston movement, and consequently the position of the V-block and hammer, is controlled by a small three-way valve conveniently located within easy reach of the operator's hand. The air hammer at the front of the machine is controlled by a foot treadle.

A small equalizing reservoir, welded in place under the table plate, is used primarily to avoid minor fluctuations in air pressure during operation of the air guns. The pressure of air to the small cylinder is limited by means of the pressure-reducing valve, illustrated, in order to avoid forcing the air hammer against the rivet head with too much pressure. The air hammer and crossway at the back of the machine move by a rack



Piston bull-ring riveting machine from the operating side

Portable electric-power unit set up for driving a cylinder boring bar

and pinion operated by the turret handle, illustrated, the operation of the air hammer itself being controlled by hand.

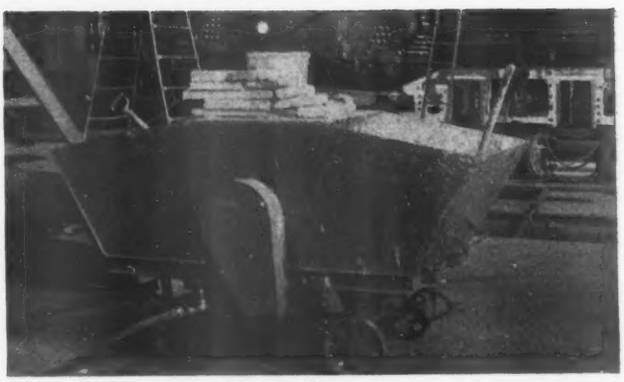
In the operation of this machine, the piston is applied, its position adjusted and the piston clamped in place as described. A hot rivet is placed in the hole which passes through the piston and bull ring. The operator then opens the three-way valve which brings the air hammer at the front of the machine against the rivet head under a substantial pressure, forces the rivet head against the piston and presses the latter firmly against the bull ring. The back hammer is then brought up against the end of the hot rivet; the front hammer is started by the foot treadle and the back hammer by the hand control valve. The hammers are permitted to operate until the new rivet head is well formed when the hammers are stopped, withdrawn from the work, the clamping cylinder released and the piston revolved to the next rivet position.

The machine is operated by a boiler maker, with a helper used to heat rivets. There is a saving of about 50 per cent in labor over the hand riveting method formerly used, and in addition a substantially better job is secured since the piston and bull ring are held more firmly together during the riveting operation which is itself unusually well done with the mechanically-supported hammers.

Electric Boring-Bar Drive

Most cylinder and valve boring operations in locomotive shops are performed with boring bars driven by air motors. By way of contrast, therefore, it may be interesting to show an electric drive unit successfully used for this operation. The power unit consists simply of three elements, namely, a ½-hp. electric motor, a speed reducer and a three-speed gear-change box with a flexible shaft connection to the boring bar.

Referring to the illustration, an Underwood boring bar will be seen set up in a locomotive cylinder, being driven through a universal drive shaft including two flexible joints and one slip joint. The power unit is mounted on a ½-in. by 18-in. by 36-in. steel table plate, equipped with suitably braced steel supporting legs and truck wheels for easy portability about the shop. The switch box and starting box are mounted on a vertical bracket bolted to the table plate, thus making the power unit compact and convenient in operation. A long electric cable, neatly wound on supporting hooks, as illustrated, permits operation of this power unit at considerable distances from the source of electric power supply when necessary.



Small portable lagging-mixing machine which can be operated close to the locomotive being lagged

The particular advantages of this power unit are its economy, ease of operation and the fact that three speeds are available for driving the boring bar. In addition, the unit is easily portable and can be readily moved to any part of the shop where it can be coupled to a boring bar and placed in operation without delay. The use of a flexible drive shaft eliminates the necessity of accurately slinging the power unit exactly parallel with the boring bar.

Portable Lagging Mixer

An unusually neat and effective portable lagging mixer is shown in another of the illustrations. It consists essentially of a welded steel box, made of $\frac{3}{16}$-in. plate, 43 in. long by 36 in. wide by 26 in. high, mounted on a shop truck frame. The spider or mixing element in this box is made of ¼-in. sheet steel, comprising four blades set at 90 deg. with each other and having 12 notched teeth per blade, the blades revolving at a speed of about 50 r.p.m.

Broken pieces of lagging with a sufficient amount of water are fed into this machine and the action of the revolving spider has the effect of shreading the lagging

and mixing it thoroughly, ready for reapplication to the boiler.

In the interest of safety, the spider is shielded with steel finger bars. The spider is driven by a reversible air motor and sprocket-chain drive, the motor being mounted under the truck frame, as shown in the illustration. Asbestos is taken from the locomotive and applied in this device, water being added and the mixture worked to just the right consistency for reapplication.

Hydraulic Press Brake And Flanging Machine

A new type of hydraulic press brake with flanging attachment which appears adapted to extensive use in railway boiler shops, has been developed recently by the Beatty Machine & Manufacturing Company, Hammond, Ind. As shown in the illustrations, this machine consists of a press brake, designed to develop 200 tons ram pressure in bending, pressing, straightening and reclaiming steel sheets; also a flanging attachment, capable of bending ¾-in. plates and lighter and, therefore, adapted for all types of flanging in connection with boiler and firebox work in locomotive shops.

Referring to the illustrations, the general construction of the machine will be apparent. It is roughly 18 ft. long by 13 ft. high and mounted on a substantial base 10 ft. wide set in the shop floor. It is driven by a 25-hp. electric motor and hydraulic equipment which serves as a single power unit for operating both parts of the machine, through control valves, either separately or together.

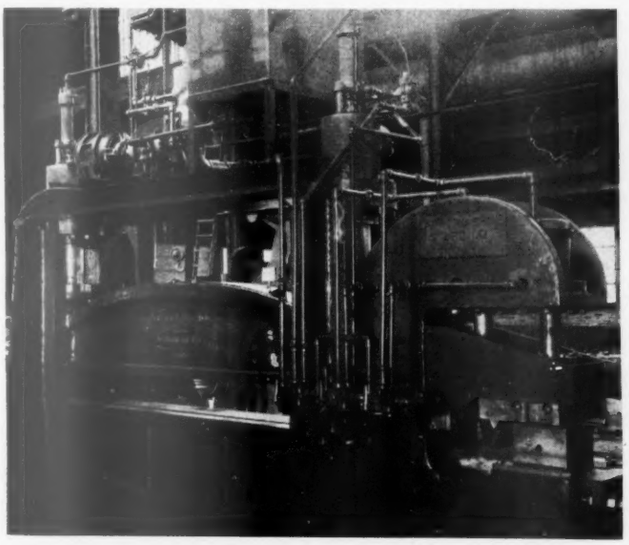
The brake press consists of a heavy cast-iron table, securely bolted to vertical cast-steel end housings which also serve as guides for the ram. The vertical housings are spaced 10 ft. 3 in. apart and tied together at the top by substantial steel I-beams which support the driving motor and the hydraulic equipment. The ram is moved by two 11½-in. hydraulic cylinders, giving a total of 200 tons ram pressure. Two small kicker cylinders on top of the machine give rapid traverse of the ram up and down as required. The maximum ram opening is 25 in. and the power stroke 14 in.

While the entire design of the machine, including the hydraulic equipment and piping is intended to give identical pressures in the two operating cylinders, slightly increased packing resistance in one cylinder, or some other condition, might cause the ram to advance more slowly on one side and, to prevent this possibility, a special mechanical attachment has been developed and applied to the back of the ram.

The flanging attachment of this machine is made of box-section cast steel of exceptionally rigid design, bolted to the press brake as indicated. Two 7¼-in. cylinders, developing 40 tons ram pressure each, are provided in the upper jaw of the attachment, the lower jaw of which is equipped with a rectangular anvil or block to support the steel plate during the flanging operation. This bottom block has rounded upper edges to give the correct inside radius of the flanged sheet, any one of four different radii being available by locating the block in the proper position on the square holding pin.

The outer cylinder is equipped with a ram which has an 8¾-in. maximum opening and 8-in. stroke, this ram being used to hold the plate firmly on the bottom block during the flanging operation. The inner cylinder is equipped with a ram having a 14-in. stroke; the lower end of this ram is guided in suitable ways on the main frame of the machine and equipped with a toggle lever arrangement which bends the sheet downward under heavy pressure as the ram moves to its lowest position. In the case of large sheets, the bend or flange is formed progressively in accordance with the usual practice.

The machine, illustrated, is installed at the Chicago Great Western shops, Oelwein, Iowa, and is the first one of its type ever built.

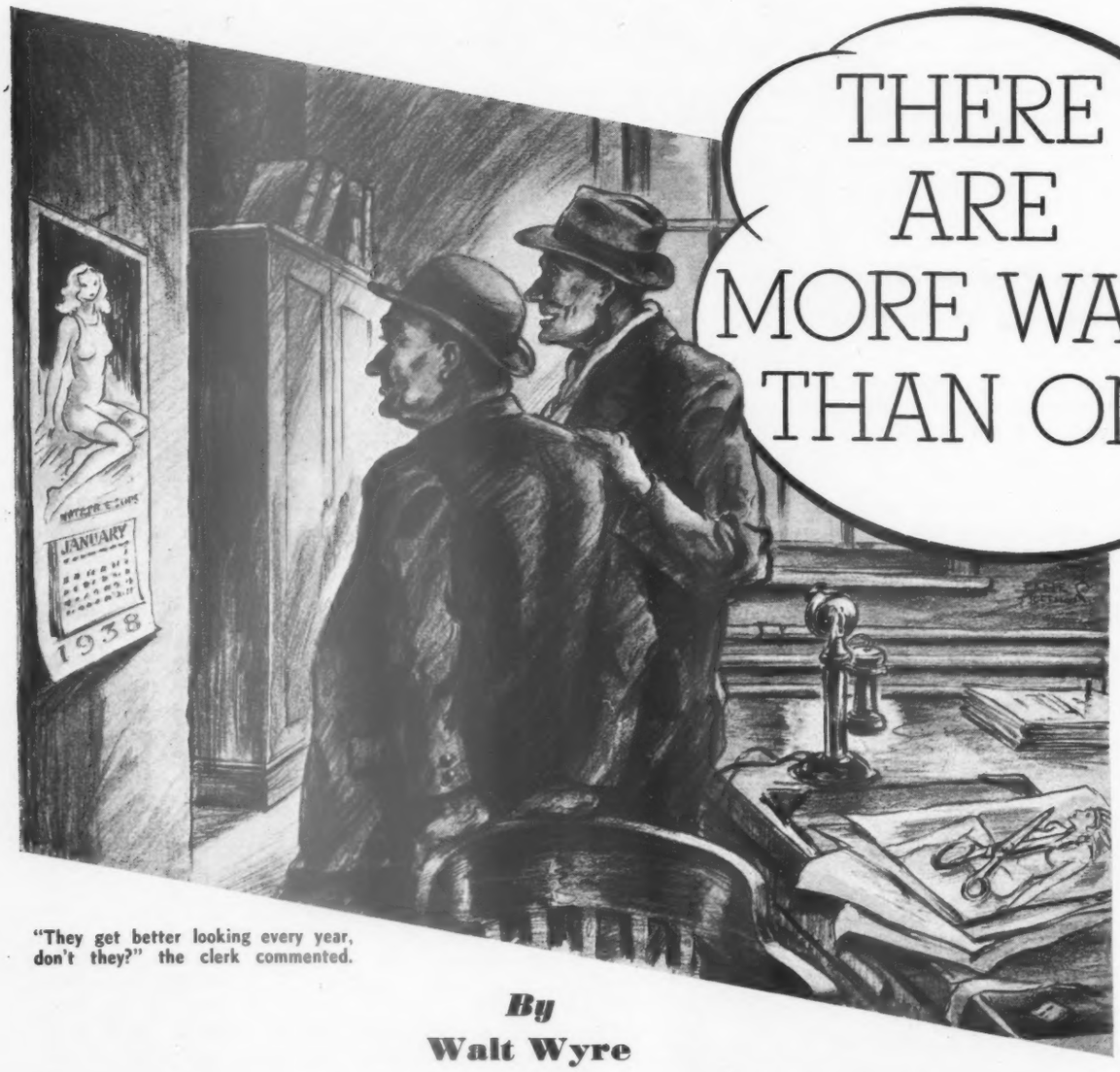


Beatty combination brake press and hydraulic flanging machine

The brake press bending a sheet of boiler plate

Flanging attachment forming the flange on a flue sheet

THERE ARE MORE WAYS THAN ONE



"They get better looking every year, don't they?" the clerk commented.

By
Walt Wyre

JIM EVANS removed the 1937 calendar from the wall in the roundhouse office and hung a new one in its place. When he had the 1938 calendar securely tacked in place, the foreman carefully cut the picture from the old one and laid it with a pile of pictures cut from calendars of previous years. Some day he was going to have the whole bunch, nearly two dozen, framed. There was one for each year he had been roundhouse foreman for the S. P. & W.

When the picture was laid away, Evans paused a moment to admire the one on the new calendar. After gazing a long moment at the scantily attired miss, his eyes lowered to the word January.

At that moment John Harris, the roundhouse clerk, came in and saw the foreman gazing at the calendar. "They get better looking every year, don't they?" the clerk commented. "Believe I could stand and look at her awhile myself."

"I was just thinking," Evans said.

"Yeah," the clerk grinned, "I have an idea you were, and I bet it wouldn't be hard to guess what you were thinking about."

"It might fool you—this time, anyway. I was thinking it's just a little over two months until the cantaloupes will start moving from the west. Every year they've caught us short of power, but this year I'm going to be ready. Soon as the holiday rush is over, I'm going to start getting locomotives in shape so that by the middle of April, when the cantaloupes come, I'll be ready for them."

"If that's a New Year's resolution, I hope you can stay with it." The clerk handed the foreman a couple of letters.

Both letters were from the master mechanic. Evans read one of them: "Engine performance during the holiday season has been very poor. We had three failures in the past fifteen days which is entirely too many. In addition we have had numerous delays that should have been prevented. Every effort must be made to improve engine performance out of Plainville."

Evans laid the letter down and picked up the other and read: "The holiday rush is about over and it is to be expected that business will fall off considerably in the next few weeks. As a result, our appropriation for the month of January has been reduced twenty per cent. You will arrange working forces to stay within the reduced allowance."

Evans laid the letter on the desk, picked up a pencil, and began to figure. He covered a sheet of yellow clip with figures, then wadded the paper and threw it in the waste basket.

"Hell! It can't be done!" he said aloud.

"What's that that can't be done?" Harris then asked.

"Why, keep the engines going with a twenty per cent cut in the allowance! The way we have been running them the past three weeks, every engine we've got should go over the drop-pit." Evans snorted, clapped his hat on and headed for the roundhouse. On the way he met the hostler coming towards the office.

"The 5082, it's called for 9:20 and it's not ready to come out yet," the hostler said.

Evans looked at his watch, 8:35, and quickened his pace. In the roundhouse, the foreman found the left main rod not yet up on the 5082 and the machinist doing the work nowhere around the locomotive. He found the nut-splitter in the machine shop arguing with a lathe hand.

"What the matter?" Evans asked. "Don't you know the 5082 is called for 9:20?"

"The bushing is too small for the pin," the machinist said.

"It'll run, all right," the lathe man said. "The pin is out of round and tapering. Grease it good—it'll run."

"Have you split the bushing?" Evans asked.

"Yes."

"Well, let's see what it looks like," the foreman said. "Bring it down to the engine."

Both men were right. The bushing was too tight and the pin was egg-shaped and tapering.

If the bushing was taken back to the lathe and a cut taken out, that meant a delay. If it ran hot, it meant a delay. With luck, it might make it.

"Drive it in," Evans said. "Pour some oil on the pin and be sure the rod cup is well filled."

THE bushing ran hot, as Evans expected it would; but the run was made to the next division point without loss of time, as he had hoped. The incident reminded him of something that he already knew. They were using too much brass, renewing too many rod bushings, and a large percentage of it was on account of the conditions of the pins. Most of them were like the left main pin on the 5082. That was one of the conditions he had intended to correct before the rush of the cantaloupe season started.

The engineer who came in on the 5076 reported both piston valves blowing. Evans told Henry Cox to pull the valves.

"What do they look like?" Evans asked the machinist. "Will rings fix 'em up?"

"Rings might do for a couple of trips, but what they need is new bushings and bull rings."

The foreman calipered the bushings and bull rings and headed for the storeroom.

"Do you want me to cut the bushings out?" the machinist inquired as Evans left.

"Hell, no!" Evans said over his shoulder. "Chances are we'd have to wait two weeks until the store department could get some in."

He was at least partly right. The storekeeper showed Evans where valve bushings and bull rings would be if they had any. Like a magician getting ready to pull rabbits from a hat, the storekeeper waved his arms as though challenging the foreman to find a valve bushing or bull ring hidden any place. Unlike the magician, the storekeeper produced no bushings. All he could show was copies of requisitions.

"Build up the bull rings with bronze," Evans told the machinist.

"We're running over the allowance every day," the clerk told Evans that afternoon. "Just thought I'd remind you of that before you go too far into the red.

"Yeah, I knew we were running over, but dammit, can't help it!" Evans wrenched a cover off his plug of "horseshoe." "We've been pounding hell out of the engines, barely holding them long enough to get what jobs had to be done." Evans squirted a deluge of tobacco juice in the cuspidor. "Just because business shows signs of falling off is no reason the ones we do run don't have to be worked."

The foreman went back into his cubby hole that served as his "private" office to do a little figuring. Thirty minutes later he came out without having arrived at any satisfactory conclusion.

"Guess we'll have to cut off some men," Evans told the clerk, "but I don't see who we can get along without."

"Do you want me to make a bulletin?" the clerk asked.

"Yeah," Evans said resignedly. "Let's see —"

The engine inspector interrupted the conversation by coming in at that moment. "The 5091 that just came in —" the inspector began.

"Guess she needs a new locomotive run under the whistle," Evans interrupted.

"No, except for driving boxes pounding, the booster not working, a cut trailer journal, spring hangers worn, a few rod bushings that need renewing, and the feedwater pump won't supply the boiler, she's a pretty good engine."

"Is that all?" Evans inquired.

"That's about all I noticed," the inspector replied. "You see, I didn't finish looking her over after I checked the cab card and found she is due a five-year test tomorrow."

"I'll go look at it myself." The foreman started to go when the inspector stopped him.

"I've got the cab card with me."

The inspector was right, the five-year test was due.

"Never mind the bulletin. With a five-year test in addition to other work, we can't cut off men now. Besides," he added, "I think there'll be enough on the 5091 for classified repairs. That'll take a little off running repairs."

Evans left the office determined that he would at least hold one locomotive until it was in first class condition. He stopped at the inspection pit and told the hostler to run the 5091 over the drop-pit.

THE week went by with very little increase in the net deficit. On the other hand, prospects of balancing the budget for the month seemed as unlikely as the present session of Congress balancing the national budget. Unlike our idealistic lawmakers, Evans knew something had to be done about it. Politicians may point with pride and oratorical eloquence at various Babalonian projects as explanation of governmental deficits, but railroad officials as a rule are not interested in either oratory or fairy tales.

Saturday afternoon Evans sat down in his office to do a little figuring and make a list of the number of men to be cut off. According to figures given him by the clerk, they were nearly four hundred dollars over for the month with fifteen days gone, at least fifteen days would be gone at midnight. Thirteen more week days and three Sundays in the month—Evans chewed the end of his pencil and cocked his eyes at the ceiling. Four hundred dollars over and the 5091 already carrying one hundred dollars more than had been worked on her! At least fifty dollars a day had to be cut off on week days for the rest of the month. Four me-

chanics, four helpers, and two laborers would just about make it. How he would ever manage to get the 5091 finished and do the necessary running repair on engines too was something else to worry about.

But what's one worry more or less in a roundhouse foreman's lot—he has so many they're like snowflakes in a drift.

The telephone rattled abruptly. The clerk answered it. Evans paused with pencil poised as he listened to the clerk.

"Yes, clerk talking . . . What? . . . O.K., I'll tell him. Call you back in a minute."

"What is it?" Evans asked. He knew by the tone the clerk used something was wrong.

"Main pin broke on the 5077," the clerk replied. "Tore up pretty bad, the dispatcher said."

"Where did it happen?"

"Near Middleton. Dispatcher wants to know what engine you're going to send out and he says a machinist will have to be sent to get the 5077 in shape to move."

"It'll be the 5072," Evans said as he opened the door and started for the roundhouse walking so fast he skidded going around the turntable.

The foreman lined up a machinist and helper for the road trip. He told them to load a cutting torch and other tools on the engine to take along.

The 5077 came in to Plainville about seven-fifteen next morning. She was a sorry sight. The air pump was broken, the left cylinder head knocked off and a chunk out of the cylinder casting with it, to say nothing of bent and twisted rods. On top of that there was a little matter of nearly thirty dollars overtime to be considered.

Evans looked the engine over, then told the hostler to shove her in the house. He could start worrying about fixing it up Monday. There was a little matter of figuring how to get a platoon of work done with a squad of men without additional overtime, delays or failures.

MONDAY morning Evans rose at his usual hour, early, but not so very bright. It's too much to expect of any one to be bright getting up from a nice cozy bed when all the neighbors are just turning over to begin their beauty nap. He ate hurriedly, gave his wife half a bushel of kisses—two pecks—and rushed out to find one flat tire on the car. Evans walked.

Some people might have enjoyed the rosy dawn that greeted the foreman as he crunched gravel down the tracks towards the roundhouse. A fleecy layer of cumulus clouds glowed iridescently tinted by the reddish rays of the yet hidden sun. It was a beautiful dawn but Evans didn't enjoy it. The clouds reminded him of the condition of the allowance, in the red.

Two letters were on his desk when Evans reached the office. There was other mail, routine matters to be handled and such, but two of the brown envelopes contained letters about subjects the foreman wasn't anxious to have brought up. In one of the letters the master mechanic hinted rather broadly that engine performance should be improved. Evans read in part: "Engine performance for the past three weeks has been deplorable." Deplorable is the word the master mechanic uses when he wants to emphasize the fact that a condition is getting to the point that if something isn't done immediately, he, the master mechanic, will do something himself.

The other letter ended with: "Plainville has consistently overrun the monthly allowance. Other points on the division have managed to stay within theirs. No excuse will be accepted for overrunning of allowances for the current month."

"Yeah—other points!" Evans snorted aloud, "Sanford has stayed within their allowance by sending all their wrecks, annual and five-year tests to us, like they did the 5091." The foreman bit off a hunk of "horseshoe" and went to the roundhouse.

AFTER getting the work lined up for engines that had to be run, the foreman looked the 5077 over. His first idea was to send the damaged locomotive to the backshop for repairs. He carefully inspected the damaged left cylinder and decided it wasn't damaged too bad to be welded locally. Besides the chunk broken out there was a crack extending back lengthwise of the cylinder about eleven inches. The crack could be V-ed out and welded. He decided to have a hole drilled at the end of the crack to keep it from progressing. Where the chunk was broken out would have to be built up. A row of studs would serve as support for the bronze he would use to build it up with and strengthen the weld. The air pump would have to be replaced.

The foreman walked away from the 5077 shaking his head. There was a lot of work needed to put the engine in condition to run again. How could he stay within his allowance and get the work done too? The master mechanic had said he would accept no excuse.

Evans went back to the office to finish the bulletin he had started Saturday. He wrote out three machinists and helpers, one boilermaker and helper, one coppersmith and helper, three laborers.

Three machinists—that would get Johnson, the best man he had on the drop-pit. That would slow up work on the 5091. Then the coppersmith was needed to finish the pipe work and put the jacket on. The boilermaker would get Barton, the only man he could be sure of doing a good job of welding the broken cylinder. Well, if it had to be done, it had to be. He picked up the piece of clip with the list on it and started to walk over to the clerk's desk.

The phone rang. "It's the superintendent's chief clerk; wants to talk to you," the roundhouse clerk said.

"Hello . . . Yes."

". . . a pile driver and two ditchers, they'll be here this afternoon on the local."

"O.K., we'll get started on them first thing tomorrow . . . Yes, I'll put all the men I can spare to work on them and get them finished soon as possible."

When Evans hung up the receiver he was grinning as he hadn't in several days.

"Want me to make out the bulletin?" The clerk picked up the sheet with the list of men on it to be cut off.

"Tear it up!" Evans said.

"But what about the allowance?" the clerk asked. "Did you get it increased?"

"Not exactly," Evans grinned, "but there'll be a pile driver and a couple of ditchers in here tomorrow to be overhauled. It's going to take a lot of work to get them ready for spring work."

"I see," John Harris nodded. Eight years as roundhouse clerk had taught him a few things. "I'll watch and see that all of the time that should be is charged to the pile driver and ditchers."

"Just one thing," Evans paused in the doorway, "if those ditchers are gasoline driven, be careful about charging boilermakers' time to them."

The foreman headed for the roundhouse whistling what purported to be "Casey Jones."

(*Turn to next left hand page*)

Bulletin No. 1

ANNOUNCING
AN IMPORTANT NEW SERVICE

ASSUMING that every wheel turned out of every plant is as good as the best wheel turned out of any plant, no one can deny that the

CHILLED CAR WHEEL

is the most economical for railway service.

A SCIENTIFIC inspection service has been inaugurated to accomplish this purpose and which covers every detail of manufacture.

Five steps designed to assure the greatest possibility of uniformity of **CHILLED CAR WHEELS**

1. A STRINGENT and standard set of manufacturing specifications with uniform interpretation and administration.
2. AN independent **A. M. C. C. W.** inspector stationed at each wheel plant.
3. DAILY operating reports from each plant covering every manufacturing process.
4. DETAIL analysis of daily reports by supervisory organization at Chicago and prompt corrective measures where necessary.
5. PERIODIC inspection of plant operation by supervisory staff.

This scientific inspection service is already rapidly becoming effective.

"EVERY WHEEL SHALL BE AS GOOD AS THE BEST"

ASSOCIATION OF MANUFACTURERS OF CHILLED CAR WHEELS
[illegible] Blvd., Chicago, Illinois 230 Park Avenue, New York, N. Y.

Locomotive Boiler Questions and Answers

By George M. Davies

(This department is for the help of those who desire assistance on locomotive boiler problems. Inquiries should bear the name and address of the writer. Anonymous communications will not be considered. The identity of the writer, however, will not be disclosed unless special permission is given to do so. Our readers in the boiler shop are invited to submit their problems for solution.)

Reasons for Removing Flexible Staybolt Caps

Q.—What are the reasons for removing the caps from flexible staybolts on a locomotive?—J. M. D.

A.—The reasons for removing the caps from flexible staybolts on locomotive boilers are as follows: (1) To renew a broken staybolt; (2) to renew a fractured sleeve; (3) to inspect a staybolt; (4) to remove and reapply staybolts when applying new firebox sheets; (5) to replace a defective cap or cap gasket and (6) to comply with following I. C. C. rule:

"23 *Method of Testing Flexible Staybolts with Caps.* Except as provided in paragraph (*b*) all staybolts having caps over the outer ends shall have the caps removed at least once every two years and the bolts and sleeves examined for breakage. Each time the hydrostatic test is applied the hammer test required by Rules 21 and 22 shall be made while the boiler is under hydrostatic pressure not less than the allowed working pressure.

"(*b*) When all flexible staybolts with which any boiler is equipped are provided with telltale holes not less than 3/16 in. nor more than 7/32 in. in diameter, extending the entire length of the bolt and into the head not less than one-third of its diameter, and these holes are protected from becoming closed by rust and corrosion by copper plating or other approved method, and are opened and tested, each time the hydrostatic test is applied, with an electrical or other instrument approved by the Bureau of Locomotive Inspection, that will positively indicate when the telltale holes are open their entire length, the caps will not be required to be removed. When this test is completed the hydrostatic test must be applied and all staybolts removed which show leakage through the telltale hole.

"The inner ends of the telltale holes must be kept closed with fireproof porous material that will exclude foreign matter and permit leakage of steam or water, if the bolt is broken or fractured, into the telltale hole. When this test is completed, the ends of the telltale holes shall be closed with material of different color than that removed and a record kept of colors used.

"(*c*) The removal of flexible staybolt caps and other tests shall be reported on the report of inspection Form No. 3 and a proper record kept in the office of the railroad company of the inspections and tests made.

"(*d*) Firebox sheets must be carefully examined at least once every month for mud burn, bulging, and indications of broken staybolts.

"(*e*) Staybolt caps shall be removed or any of the above tests made whenever the United States inspector considers it desirable in order to thoroughly determine the condition of staybolts or staybolt sleeves."

Requirements *a*, *b* and *c* of Rule 23 are interpreted as follows:

"(*a*) When locomotives are stored for one or more full calendar months, the removal of flexible staybolt caps for the purpose of inspection will be due after 24 calendar months' service, provided such service is performed within three consecutive years. Portions of calendar months out of service will not be counted. Time out of service must be properly accounted for by out-of-service reports filed with the United States inspector and notation of months claimed out of service must be made on the back of each subsequent inspection report and cab card.

"(*b*) A locomotive stored when renewals of flexible-staybolt cap removals are due need not be given such test until immediately prior to being returned to service.

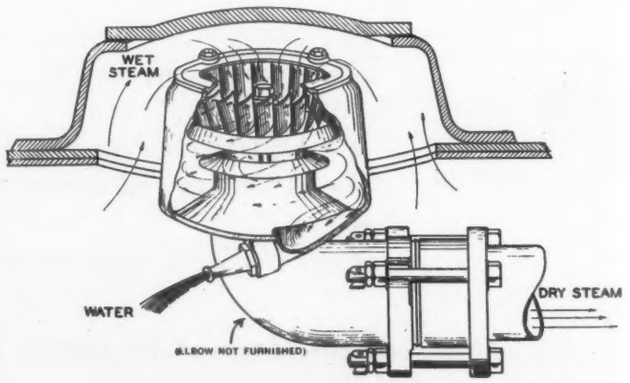
"(*c*) When locomotives are being given their annual inspection and test, flexible staybolt caps should be removed at the time of making this inspection, if they become due for removal before another annual inspection is due, and their removal shown on Form 3. One of the principal reasons urged for extending the time for removal of flexible-staybolt caps from 18 months to two years was for the purpose of bringing the test due at every second annual inspection."

Tests of Elesco Tangential Steam Dryer

Recent tests made by the Superheater Company, New York, with the Elesco Tangential steam dryer on modern locomotives has shown the ability of this device to handle large quantities of water. The tests were made by spraying water into the dryer, in quantities up to 20 per cent of the water evaporated by the boiler. The amount of water sprayed into the dome was accurately measured with a flowmeter and the drop of superheat was read on a pyrometer. The results obtained are shown in the accompanying table. Attention is called to test run No. 2, when 6,756 lb. of water were sprayed into the dome, equivalent to 16.4 per cent moisture and resulting in only a 36-deg. drop in superheat. It is estimated that if it were not for the dryer, there would have been a 244-deg. drop in superheat.

Tests of an Elesco Tangential Steam Dryer

Test No.	1	2
Steam flow through dry pipe, lb. per hr.	34,562	35,073
Water sprayed into dryer:		
Lb. per hr.	1,999	6,756
Per cent	5.5	16.4
Actual drop in superheat, deg. F.	11	36
Calculated drop in superheat if sprayed water had not been separated, deg. F.	87	244
Moisture in dry pipe:		
Lb. per hr.	212	723
Per cent	0.6	2.1
Moisture returned to boiler, lb. per hr.	1,787	6,033
Dryer efficiency, per cent	89.5	89.1



Application of an Elesco tangential steam dryer

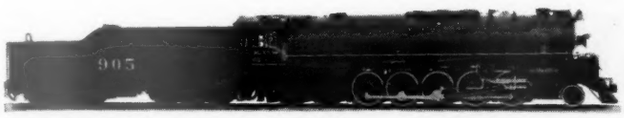
(Turn to next left-hand page)

Passenger Power

Boston & Maine R. R.

Southern Pacific Company

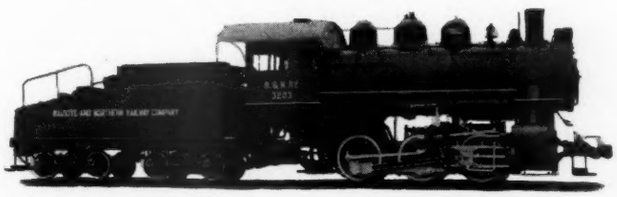
Freight Power



Kansas City Southern Ry.

Pere Marquette Ry.

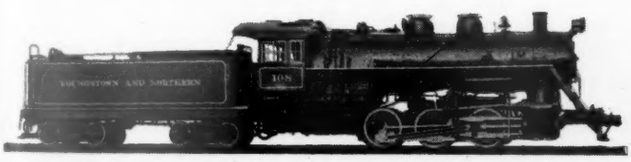
Switching Power



Bauxite & Northern Ry.

New York Central System

Chicago & Illinois Midland Ry.

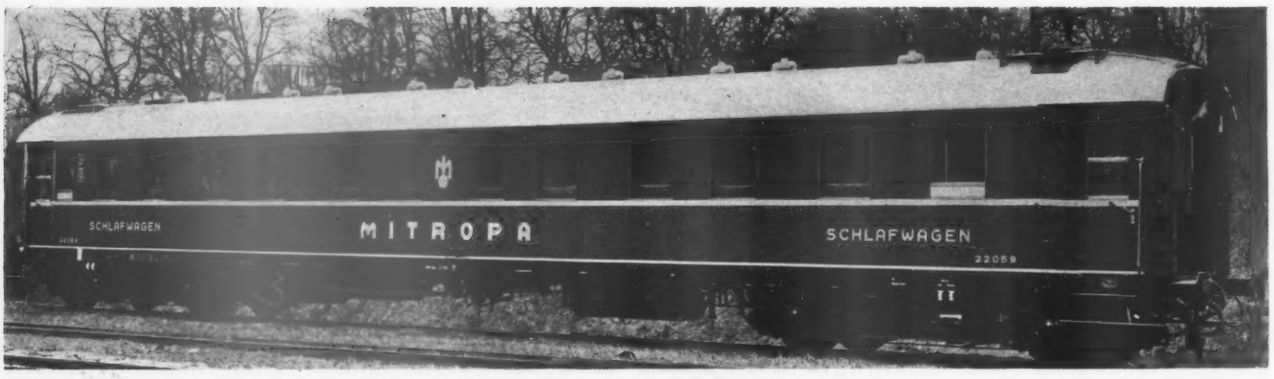


Youngstown & Northern R. R.

Newburgh & South Shore Ry.

1937 Lima Built Power

LIMA LOCOMOTIVE WORKS, INCORPORATED, LIMA, OHIO



The modern Mitropa sleeping car

NEWS

C. & O. Huntington Storehouse Destroyed by Fire

THE storehouse of the Chesapeake & Ohio shops at Huntington, W. Va., was destroyed by a fire of undetermined origin on November 28. Officers estimated the loss at $100,000, all of which is covered, however, by insurance. The blaze was confined to the storehouse proper by a protective fire wall and did not spread to the remainder of the shop building, which will remain in operation. The shop telephone system also suffered minor damage.

Improvement Programs

Atchison, Topeka & Santa Fe.—Directors of the Santa Fe have authorized the purchase of stainless steel passenger cars and Diesel locomotives to cost $4,800,000.

Norfolk & Western.—A program of general improvements for the immediate future, involving an expenditure of approximately $3,700,000, has been announced by the Norfolk & Western. The program includes among other items the purchase of shop tools to cost about $200,000 and 4,000 sets of improved (AB) air brakes for application to freight cars.

St. Louis-Southwestern.—Expenditure of $1,558,000 by the St. Louis-Southwestern for improvements to rolling stock and right-of-way in 1938 has been approved by the federal district court. Of this amount, $565,000 is for 50 freight cars and two passenger cafe cars and $157,000 is for shops and roundhouses.

Locomotive Tire Manual

IN Circular D.V.-929 just issued by the A.A.R. Mechanical Division through the office of Secretary V. R. Hawthorne, the statement is made that one of the most important subjects before the mechanical department of American railways is that of locomotive tire work. Large sums of money are expended in the purchase, machining and application of tires.

Based upon the reports of tire failures from a large proportion of railroads of the country, the Committee on Locomotive Construction has been impressed with the lack of appreciation on the part of many shop mechanics, foremen, and even officers, of the existence of improper shop practices in effect, including care of tires in handling and storage, machining of tires and wheel centers, application and damage due to welding. It is essential that employees who are responsible for tire work in the shops and inspection on the line, should have a thorough understanding of their work. It is for this reason that this manual has been prepared and approved by letter ballot. It contains information for inspectors, mechanics and supervisors.

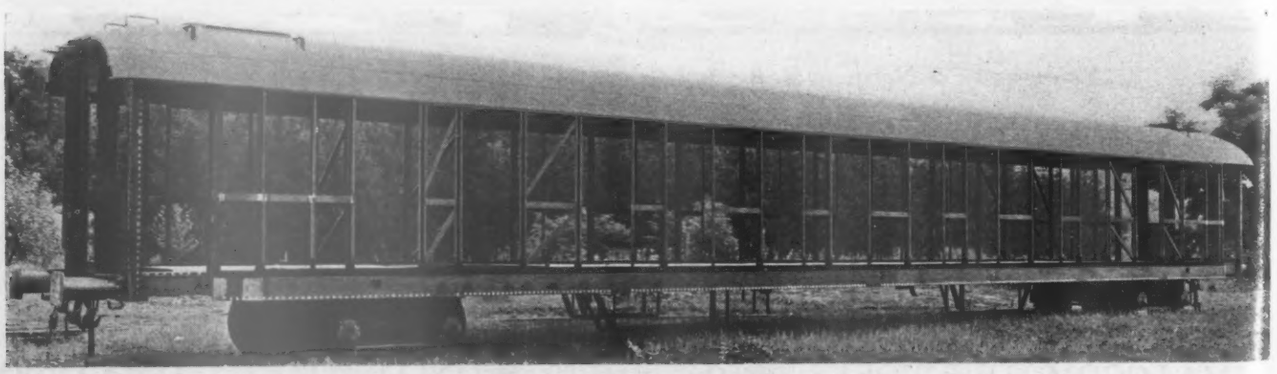
* * *

Equipment Depreciation Orders

THE Interstate Commerce Commission recently issued another series of sub-orders and modifications of previous sub-orders in No. 15100, Depreciation Charges of Steam Railroad Companies, prescribing equipment depreciation rates for 11 railroads, including the Atchison, Topeka & Santa Fe and the Pittsburgh & Lake Erie. The composite percentages, which are not prescribed rates, range from 3.34 per cent for the Washington Terminal to 10.2 for the Atlantic & Western.

The Santa Fe's composite percentage of 3.77 is derived from the following prescribed rates: Steam locomotives, 3.52 per cent; Diesel road locomotives, 6.33 per cent; Diesel switching locomotives, 4.75 per cent; refrigerator and ice cars, 4.75 per cent; other freight-train cars (wood underframe), 4.41 per cent; other freight-train cars (steel and steel underframe), 3.59 per cent; stainless steel lightweight passenger-train cars, 3.89 per cent; other passenger-train cars, 2.9 per cent; floating equipment, 2.87 per cent; work equipment, 4.8 per cent; miscellaneous equipment, 12.6 per cent. The 3.66 composite percentage for the Pittsburgh & Lake Erie is derived from the following prescribed rates: Steam locomotives, 3.8 per cent; freight-train cars,

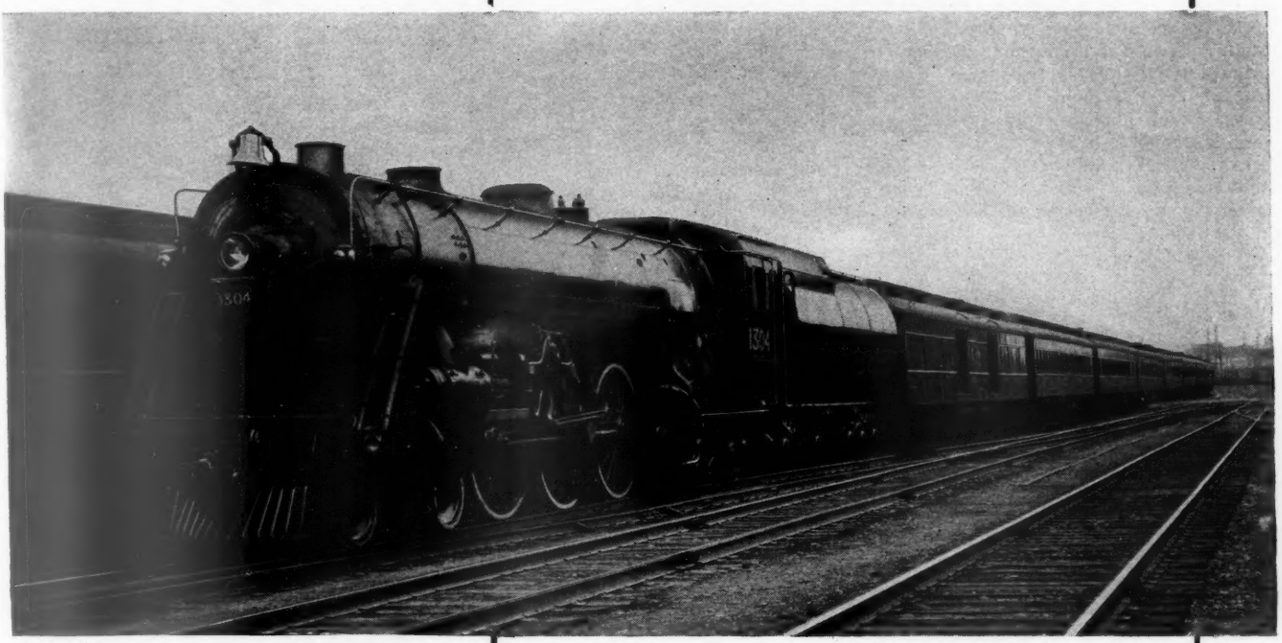
(*Continued on next left-hand page*)



Steel frame construction of modern Mitropa cars

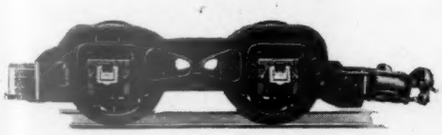
The structures are of the stressed skin type—Length over buffers, 77 ft. 1 in.; width overall, 9 ft. 4¼ in.; distance between truck centers, 53 ft. 1 in.—Service weights: First- and second-class sleeping car (22 berths), 117,500 lb.; third-class sleeper (3 berths each in 13 compartments), 117,700 lb.; dining car, 112,400 lb.

MODERN POWER



. . . is Balanced Power

The trend of Modern Locomotive design is definitely towards minimum weight on drivers, reduced dynamic augment, high starting and accelerating power and high horsepower capacity at high road speeds. »»To meet these objectives the high horsepower required in the operating range of speed is provided by the main cylinders and the additional tractive effort required for starting and rapid acceleration to road speeds is provided by the Booster.»» Such a locomotive, operating at the high speeds and high capacities of modern railroading, insures lower track maintenance costs, increased economies of operation and maintenance and greater net returns from every train it hauls.



All replacement parts furnished by Franklin Railway Supply Company are identical as to materials, design, clearances and workmanship with the parts they replace. They guarantee the same unfailing reliability of service.

FRANKLIN RAILWAY SUPPLY COMPANY, INC.

NEW YORK CHICAGO MONTREAL

3.68 per cent; passenger-train cars, 3 per cent; work equipment, 3.46 per cent; miscellaneous equipment, 18.26 per cent.

Stainless Steel Exhibit in New York Museum

AN exposition of stainless steel has opened for a period of several months in the New York Museum of Science & Industry, Rockefeller Center, New York. The exhibit, which is sponsored jointly by the Electro Metallurgical Company, Unit of Union Carbide & Carbon Corp., New York, and the museum, portrays the history, development, production, fabrication and uses of stainless steel products. Among the many fields of application receiving emphasis is that of transportation equipment.

In this connection, the "Shotweld" system of joining stainless steel in the manufacture of railroad rolling-stock is demonstrated by special operators, and sections of car structures are placed for inspection.

New Equipment Orders and Inquiries Announced Since the Closing of the December Issue

LOCOMOTIVE ORDERS

Road	No. of locos.	Type of loco.	Builder
Mexican Ry. Co.	3*	4-6-2	Montreal Locomotive Works
White Pass & Yukon	1	2-8-2	Baldwin Locomotive Works

LOCOMOTIVE INQUIRIES

Canadian National	6	4-8-4†	.....
Chesapeake & Ohio	14	18,000-gal. tenders	.....
Norfolk Southern	5	2-8-4	.....

FREIGHT-CAR ORDERS

Road	No. of cars	Type of car	Builder
Louisiana & Arkansas	275	70-ton flat‡	American Car & Foundry Co.

FREIGHT-CAR INQUIRIES

Canadian National	2,000	Box	.....
Western Maryland	500	50-ton box	.....
	100	50-ton gondolas	.....
	500	50-ton hopper	.....
Western Pacific	250	50-ton box	.....
	100	50-ton flat	.....
	50	50-ton gondola	.....

PASSENGER-CAR INQUIRIES

Road	No. of cars	Type of car	Builder
Canadian National	5	Mail and express	.....

* These locomotives will have 20-in. by 28-in. cylinders, 69-in. driving wheels and will weigh 250,000 lb. in working order.
† 6400 type, for service on the Grand Trunk Western.
‡ For handling pulp wood.

Supply Trade Notes

CHARLES B. COLLINS, assistant vice-president of the American Car & Foundry Co., at St. Louis, Mo., has resigned.

A. E. BIDDLE, vice-president of the Cardwell-Westinghouse Company, Chicago, has been elected executive vice-president, and J. M. Hall, chief engineer, has been elected vice-president.

SAMUEL F. PRYOR, JR., has been appointed assistant to the president of the American Brake Shoe & Foundry Co. Mr. Pryor is also vice-president of the Southern Wheel Division of this company, with headquarters at New York. He is a director of many industrial organizations, including the National Bearing Metals Corporation, and is director and chairman of the executive committee of the Vanadium Corporation of America. Mr. Pryor is 39 years old and has been associated with the American Brake Shoe & Foundry Co., Southern Wheel Division, since 1924, serving as molder's helper, molder, and assistant superintendent. He entered the sales department of the company in 1927 and was elected vice-president in 1930. The American Brake Shoe & Foundry Co. consists of The American Brakeblok Division, Southern Wheel Division, Ramapo Ajax Division, American Manganese Steel Division, and its affiliate, The National Bearing Metals Corporation.

Greystone Studios, Inc.
Samuel F. Pryor, Jr.

E. T. SCHROEDER, 1205 Syndicate Trust building, St. Louis, Mo., has been appointed sales representative, in that territory, for the Hennessy Lubricator Company, 75 West street, New York.

BARD BROWNE, assistant to vice-president and N. T. McKee, general service manager of the Superheater Company, New York, have been elected vice-presidents, with headquarters, as heretofore, at New York.

B. C. WILKERSON, chief service engineer of The Superheater Company, has been appointed service manager, with headquarters at New York. During 1935 Mr. Wilkerson was in charge of the New England territory and on January 1, 1936, was appointed chief service engineer.

THE TRANE COMPANY, LaCrosse, Wis., has established a transportation department at 852 North Rush street, Chicago. J. Whalen of the Chicago branch and J. Hicks of the LaCrosse air-conditioning department have been transferred to the new department.

PHIL HUBER, vice-president and assistant general manager of the Ex-Cell-O Corporation, Detroit, Mich., and one of its organizers in 1919, has been elected president and general manager to succeed N. A. Woodworth, who has resigned because of ill health.

T. M. ROBIE, who has been in charge of Diesel sales to resale manufacturers for Fairbanks, Morse & Company, has been appointed manager of the Diesel sales division at Chicago.

MURRAY B. WILSON of the Detroit sales district office of the American Rolling Mill Company, Middletown, Ohio, has been appointed manager of the New York sales district, to succeed Cliff Spear, who has been forced to curtail his activities because of ill health.

JOHN F. MACENULTY, vice-president in charge of sales of the Pressed Steel Car Company, Inc., Pittsburgh, Pa., was elected president and a member of the board of directors, and George H. Fleming, who had served as director and vice-president in charge of the Pittsburgh office, was elected executive vice-president, at a recent meeting of the board. Mr. MacEnulty began work with the Pressed Steel Car Company in February, 1899. He was appointed engineer of construction in 1903, and the following year was transferred to the New York sales department. In 1907 he was appointed general superintendent of the Western Steel Car & Foundry Co., a sub-

John F. MacEnulty

(*Continued on next left-hand page*)

NO. 10 OF A SERIES OF FAMOUS ARCHES OF THE WORLD

WHARNCLIFFE VIADUCT

HANWELL, ENGLAND

The Wharncliffe Viaduct on the route of the Great Western Railway at Hanwell, England, consists of eight semi-elliptical brick arches of 70 feet span springing from stone-capped piers. The base area of these piers is 252 square feet. This Viaduct was constructed one hundred years ago, 1836-1837. It is 896 feet in length and 65 feet high. It was named after Lord Wharncliffe as a compliment to the Chairman of the House of Lords Committee which authorized the railroad. This viaduct, originally constructed for two lines of way, was widened to take four tracks in 1875.

* * *

A complete Security Brick Arch in the locomotive firebox is essential to full fuel economy. To facilitate locomotive arch maintenance, the American Arch Company maintains an adequate stock of Security Arch Brick at conveniently located points throughout the country.

THERE'S MORE TO SECURITY ARCHES THAN JUST BRICK

HARBISON-WALKER REFRACTORIES CO.

Refractory Specialists

AMERICAN ARCH CO.
INCORPORATED
60 EAST 42nd STREET, NEW YORK, N. Y.
Locomotive Combustion Specialists

sidiary of the Pressed Steel Car Company, and two years later, was appointed general manager of the same company. In June, 1912, Mr. MacEnulty was appointed sales manager of the Pressed Steel Car Company and subsidiaries, and from January, 1916, served as vice-president and a director until the company's recent reorganization, when he became vice-president in charge of sales of the Pressed Steel Car Company, Inc.

THE ECLIPSE AIR BRUSH COMPANY, INC., has removed its office and factory to 390 Park Avenue, Newark, N. J., the building formerly occupied by the company having been damaged by fire on December 14.

THE WATSON-STILLMAN COMPANY, Roselle, N. J., has transferred its district sales office from Columbus, Ohio, to Detroit, Mich. J. C. Grindlay, western sales manager, is in charge of the new office, which is located in the Book building.

W. E. WECHTER, assistant manager of the Oil & Gas Engine division of the Worthington Pump and Machinery Corporation, at Harrison, N. J., has been appointed manager of oil & gas engine sales, Atlantic division, to succeed R. L. Howes, resigned. Mr. Wechter now has his headquarters at 2 Park avenue, New York City.

CHARLES T. RIPLEY, former chief mechanical engineer of the Atchison, Topeka & Santa Fe, has been appointed chief engineer of the newly organized Technical Board of the Wrought Steel Wheel Industry, which has its office in the South Michigan building, Chicago. This organization was formed by the American Rolling Mill Company, the Bethlehem Steel Company, the Carnegie-Illinois Steel Corporation, the Edgewater Steel Company and the Standard Steel Works Company. The purpose of the board is to make an organized and co-ordinated attack on the technical problems presented by the increasingly difficult requirements of railroad service, to collect full information regarding the performance of wheels and to establish channels of communication and co-operation between the wrought-steel-wheel manufacturers and the railroads on engineering problems.

J. H. VAN MOSS, who has been appointed western sales manager of the American Car and Foundry Co., with headquarters at Chicago, as noted in the December issue of the *Railway Mechanical Engineer*, was for many years connected with various railroads. In 1918 he served as eastern sales representative for the Pennsylvania Tank Car Company and the Pennsylvania Tank Line. During the period from 1918 to 1927 he gained promotion to the vice-presidency of both companies. Subsequently he was elected to the presidency of the Pennsylvania Tank Car Company, meanwhile retaining the vice-presidency of the Pennsylvania Tank Line. Early in 1927 he entered the service of the Shippers Car Line Corporation, subsidiary of the American Car and Foundry Co., and in October, 1934, became associated with the parent company as sales agent. In December, 1936, he was appointed assistant vice-president of the American Car and Foundry Co.

ERNEST P. WAUD, vice-president of the Griffin Wheel Company, Chicago, has been elected president, to succeed Frank L. Whitcomb, who has been elected vice-chairman of the board of directors. Mr.

Ernest P. Waud

Waud was educated at St. Paul's school, Garden City, Long Island, N. Y., and Cornell University. He entered the employ of the Griffin Wheel Company in 1905 as inspector of chilled railroad car wheels and was later appointed chief inspector, department manager and assistant treasurer. In 1919 he was elected a vice-president, which position he has held until his recent election. Mr. Whitcomb has been associated with the Griffin Wheel Company since 1889. He was elected president in 1913, succeeding Thomas A. Griffin, who was the founder and first president of the company.

J. BROOKES SPENCER, president of the Ramapo Ajax Corporation and vice-president of the Southern Wheel Division of The American Brake Shoe & Foundry Co.,

(c) Bachrach

J. Brookes Spencer

has been elected vice-president of The American Brake Shoe & Foundry Co., with headquarters at New York. Mr. Spencer was born on January 15, 1888, at St. Louis, Mo., and was graduated from Yale University in 1910. He entered the employ of the Southern Wheel Company, a subsidiary of The American Brake Shoe & Foundry Co., in 1917, and a year later became assistant to the vice-president of that company. Mr. Spencer was elected vice-president of the Southern Wheel Company in 1921, and in February, 1936, was elected president of the Ramapo Ajax Corporation, with headquarters at New York.

THE JONES & LAUGHLIN STEEL CORPORATION now has in operation the first continuous mill in Pittsburgh for the manufacture of wide steel strip and sheets and steel plates. When operating at full capacity this new mill will provide employment for 1,200 additional men. Some of the products of the mill will have railroad uses, particularly in car construction. Its annual capacity is three-quarters of a million tons. The mill, costing $25,000,000, covers twenty-three acres, extending for half a mile along the Monongahela River.

Obituary

CHARLES GILBERT, vice-president and treasurer of the Scullin Steel Company, St. Louis, Mo., died on December 1 of a heart ailment.

EUGENE J. BUFFINGTON, who retired as president of the Illinois Steel Company, Chicago, in 1932, died in that city on December 9, following an operation.

STANLEY T. SCOFIELD, assistant to vice-president of the United States Steel Corporation, died of polyneuritis in the Presbyterian hospital, Chicago, on November 30, at the age of 51 years.

FRANK B. BLACK, chairman of the board of directors and founder of The Ohio Brass Company, Mansfield, Ohio, died suddenly of a heart attack at his home on December 19. He was 72 years old.

OVERTON BERNARD CAPPS, district sales manager of The Standard Stoker Company, Inc., with headquarters at Baltimore, Md., died on December 4, at the age of 57 years in the Protestant Hospital, Norfolk, Va., after an illness of six months. Mr. Capps began his business career in 1899, with the American Locomotive Company at Richmond, Va. From 1910 until the time of his death, he was actively engaged in sales work with the Locomotive Stoker Company and The Standard Stoker Company, Inc.

W. W. ROSSER, president of the Railway Truck Corporation, Chicago, died of pneumonia on December 22. Mr. Rosser was born in Hutchinson, Minn., on November 4, 1877, and attended Hamline University. He entered the employ of the Northern Malleable Iron Company, St. Paul, Minn., in 1901 and served the Washburn Company, Chicago, from 1903 to 1905. He then entered the employ of the T. H. Symington Company, of which company he was vice-president from 1915 to 1919. From the latter year until 1930 he was vice-president of the Bradford Corporation. In November, 1937, he became president of the Railway Truck Corporation.

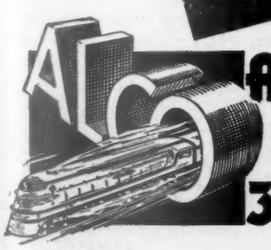
(*Turn to next left-hand page*)

WHAT PRICE *Quality?*

THE manufacture of high quality light-weight alloy steel forgings, as of any other high quality product, involves certain fixed costs. If these costs are reduced beyond a certain point, the product ceases to be "exactly right" and cannot deliver the proper dependable service.

More than a century's experience in locomotive construction has taught the American Locomotive Company how to reduce these manufacturing costs to the safest possible minimum and yet meet the severest service requirements.

Bear in mind that a locomotive is no better than its forgings—and the best forging you can buy costs you less in the long run. We feel confident that our completely modern facilities plus our skilled personnel can deliver the right kind of quality forgings at the lowest possible cost.



AMERICAN LOCOMOTIVE COMPANY

30 CHURCH STREET·NEW YORK·N·Y

Personal Mention

General

JAMES PAUL, who has retired as general superintendent motive power of the Atlantic Coast Line, was born in Lanarkshire, Scotland. He entered railroad

James Paul

service in 1885 with a predecessor of the Atlantic Coast Line as a car inspector helper. Later he was transferred to the machine shop as an apprentice. Mr. Paul subsequently served as air-brake repairman, enginehouse foreman and then as general foreman. In 1906 he became master mechanic; in November, 1925, assistant superintendent of motive power, and in March, 1927, superintendent of motive power. He became general superintendent of motive power with headquarters at Wilmington, N. C., in August, 1929, but for the past year, had been absent from his office, due to ill health.

G. C. CHRISTY, who has been appointed superintendent of motive power of the Illinois Central at Chicago, as noted in the December issue of the *Railway Mechanical Engineer*, has had a record of more than 39 years of experience with the

G. C. Christy

Illinois Central, with which road he took his first position on June 1, 1898, as a painter apprentice at Water Valley, Miss. At the end of two years he was transferred to the machine shop as a machinist apprentice. During the ensuing years Mr. Christy was advanced through various positions in the machine shop until October, 1911, when he became general foreman. In December, 1914, he was transferred to McComb, Miss., where he remained until July, 1917, when he was promoted to master mechanic, with headquarters at Vicksburg, Miss. From November 1, 1929, until his appointment as superintendent of motive power, he was superintendent of the car department, with headquarters at Chicago.

K. F. NYSTROM, who has been appointed mechanical assistant to the chief operating officer of the Chicago, Milwaukee, St. Paul & Pacific, as noted in the December issue, was born in Sweden in September, 1881, and was educated as a mechanical engineer at a Swedish university. Coming to the United States in 1905, he entered the service of the Pressed Steel Car Company as a draftsman, serving with this company until 1909, when he joined the

Karl F. Nystrom

engineering staff of the Pullman Company. After a short period of service with the latter company he became connected with the Southern Pacific in the car design department. In 1911 he became assistant mechanical engineer of the American Car & Foundry Company. Shortly thereafter he became mechanical engineer of the Acme Supply Company, and in 1913 became chief draftsman in the car department of the Grand Trunk (now part of the Canadian National). From 1918 to 1920 he served as chief draftsman in the car department of the Canadian Pacific, returning to the Grand Trunk at the end of this period as engineer of car construction. In 1922 he entered the service of the Milwaukee as engineer of car design, being appointed engineer of motive power and rolling stock in 1925. For a few months in 1927 Mr. Nystrom served as master car builder of the Milwaukee, then being appointed superintendent of the car department. As mechanical assistant to the chief operating officer, Mr. Nystrom will continue to have general supervision over the car department and, in addition, will supervise engineering, designing, construction and coordination of facilities in the mechanical department. Mr. Nystrom is president of the Car Department Officers Association.

OTTO JABELMANN, who has been appointed to the newly created position of assistant to the president in charge of research of the Union Pacific, is a

Otto Jabelmann

native of Cheyenne, Wyo., Mr. Jabelmann started service with the Union Pacific in 1906 at the age of 16 as a caller in the enginehouse at that point. He has been in the service of this company continuously since that time, with the exception of three years during which period he attended the University of Michigan. Advancing through various positions in the mechanical department, Mr. Jabelmann was appointed superintendent of shops of the Union Pacific Railroad in 1925. Eight years later he was promoted to assistant general superintendent of motive power and machinery of the system, which position he was holding in 1936, when, with the same title, he was placed in charge of the Union Pacific's newly established research bureau. Work that has been carried out under the supervision of Mr. Jabelmann includes the design of this company's various streamliners, the turbine-electric locomotive which is now nearing completion, the new 5,400-hp. Diesel-electric locomotives, the lightweight Challenger trains, lightweight freight cars, new lighting and air-conditioning methods, etc.

LEE ROBINSON, who has been appointed superintendent of equipment of the Illinois Central at Chicago, as announced in the December issue of the *Railway Mechanical Engineer*, was born in Clay Center, Kan., and after a public school education in Kansas City, served as an assistant instructor in manual training. Subsequently he left educational work to become a draftsman with a firm of consulting bridge engineers in Kansas City. His railroad career began as a draftsman and special apprentice with the Kansas City Southern at Pittsburg, Kan. Later he served three years in the mechanical department of the Missouri Pacific at St. Louis, Mo., and three

(*Continued on next left-hand page*)

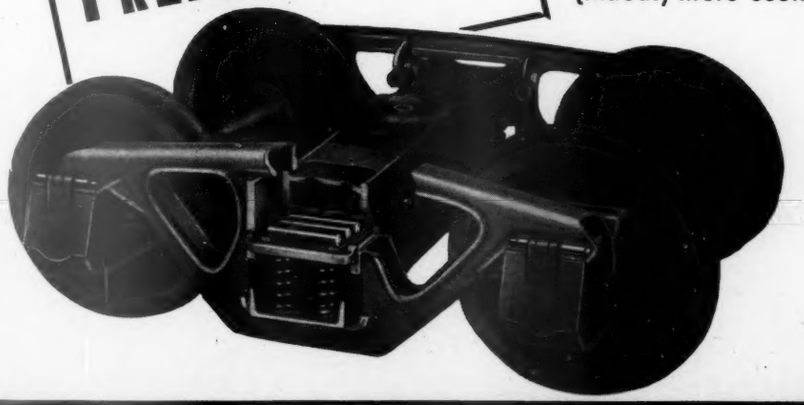
The BARBER
Lateral Motion Device

IF . . .
Passenger Cars
must have
LATERAL MOTION
why not
FREIGHT CARS?

THE Barber Lateral Motion Device is the *only* practical device providing lateral motion without the use of dangerous wearing parts found in conventional "swing hanger" trucks.

It *clears the way* for safe lateral motion in freight cars . . . where it is so badly needed to increase wheel life and to decrease costly maintenance, accidents and delays.

The difference in cost of a rigid truck and one equipped with Barber Lateral Motion is so small that the device quickly pays for itself out of savings resulting from continuous, more economical car service.



Truck Cut Away
Showing Lateral Motion
Device in Position

STANDARD CAR TRUCK COMPANY
332 SOUTH MICHIGAN AVENUE CHICAGO, ILLINOIS

years with the St. Louis-San Francisco at Springfield, Mo. He entered the service of the Illinois Central in charge of general engineering work connected with the maintenance and design of locomotives and

Lee Robinson

cars, subsequently holding the positions of mechanical valuation engineer and shop engineer. On March 10, 1930, he was appointed to the position of assistant to the general superintendent of motive power at Chicago, which he was holding at the time of his recent promotion to superintendent of equipment. Mr. Robinson was president of the Western Railway Club for the year 1935-36.

THOMAS H. DUFFY has been appointed assistant fuel service engineer of the Chesapeake & Ohio, with headquarters at Richmond, Va.

T. C. BALDWIN has been appointed superintendent of motive power of the New York, Chicago & St. Louis, with headquarters at Cleveland, Ohio, succeeding J. J. Maginn, deceased.

EMIL VON BERGEN, general air-brake, steam-heat and lubrication engineer of the Illinois Central, has been appointed to the newly created position of assistant to the vice-president and general manager—research, with headquarters as before at Chicago. In his new position, Mr. Von Bergen will make observations and studies with the view of accomplishing economies and improvements in the various phases of the company's operations.

Master Mechanics and Road Foremen

FRANK J. TOPPING, general foreman of the Hinton (W. Va.) locomotive shops of the Chesapeake & Ohio, has been promoted to the position of assistant master mechanic, Hinton division.

JOHN D. DAVENPORT, master mechanic of the Hinton division of the Chesapeake & Ohio, with headquarters at Hinton, W. Va., has been appointed master mechanic in charge of the Hinton and Clifton Forge divisions.

G. H. NOWELL, who has been appointed district master mechanic of the Canadian Pacific at Vancouver, B. C., as noted in the November issue of the *Railway Mechanical Engineer*, was born on November 13, 1884, at Montreal, Que. He entered the service of the Canadian Pacific on July 2, 1899, as a machinist apprentice at Montreal, and completed his apprenticeship on July 2, 1904. On January 15, 1913, Mr. Nowell was promoted to the position of erecting shop foreman at Ogden, Alta. He became locomotive foreman, with headquarters at Cranbrook, on September 4, 1915; division master mechanic on December 5, 1915, with headquarters at Nelson, B. C., also at Revelstoke, B. C., Lethbridge, Alta., and Regina, Sask. He was appointed district master mechanic at Moose Jaw, Sask., on July 1, 1936, and district master mechanic at Vancouver, on October 16, 1937.

G. H. Nowell

T. C. SHORTT has been appointed master mechanic of the Nickel Plate district of the New York, Chicago & St. Louis, with headquarters at Conneaut, Ohio. Mr. Shortt's former position of assistant to superintendent motive power has been abolished.

Car Department

JOSEPH A. DEPPE, who has been appointed superintendent of the car department of the Chicago, Milwaukee, St. Paul & Pacific, has been associated with the Milwaukee for more than 35 years. He entered the service of this company in April, 1902, as a helper, later serving as an inspector, billing clerk, and chief clerk to master car builder. In March, 1918, he became assistant to master car builder and two years later became general superintendent of the freight-car-shop department. In December, 1920, Mr. Deppe was promoted to the position of assistant master car builder and in August, 1927, was appointed assistant superintendent of the car department, with headquarters at Chicago.

Joseph A. Deppe

P. P. BARTHELEMY, assistant master car builder of the Great Northern, has been promoted to master car builder, with headquarters as before at St. Paul, Minn., to succeed C. H. Putnam, who has retired.

R. KNORR, shop superintendent of the Erie at Susquehanna, Pa., has been appointed supervisor of car repairs of the Western district, with headquarters at Cleveland, Ohio, to succeed C. Rhodes.

C. RHODES, supervisor of car repairs of the Western district of the Erie at Cleveland, Ohio, has been transferred to the Eastern district with headquarters at Cleveland, to replace W. H. Middaugh, supervisor of car repairs at Port Jervis, N. Y., who has been transferred to other duties.

Shop and Enginehouse

J. F. MCMULLEN, division car foreman at Buffalo, N. Y., has been appointed shop superintendent of the Erie, with headquarters at Susquehanna, Pa., to succeed R. Knorr.

Purchasing and Stores

JOHN J. CONN, assistant general purchasing agent of the Atchison, Topeka & Santa Fe System, with headquarters at Chicago, has been appointed general purchasing agent, to succeed Michael J. Collins, deceased. Mr. Conn has been in the service of the Santa Fe continuously for nearly 39 years. He was born on February 13, 1874, at Chicago, and graduated in 1889 from St. Patrick's Commercial Academy. He entered the service of the Santa Fe in February, 1899, as an office boy in the purchasing department, where he later served in various clerical capacities. In January, 1907, Mr. Conn was promoted to chief clerk in the same department and about three years later became assistant general purchasing agent.

Moffett

John J. Conn